DISCOVERY

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DISCOVERY

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The Progress of Science

A MONTHLY NOTEBOOK COMPILED UNDER THE DIRECTION OF DAVID S. EVANS

What Next?

THERE is perhaps some small psychological consolation to be derived from the fact that the war ii ending rather slowly. The war in Europe ran out to the very bitter end, continuing long after the Germans must have realised that further resistance served no useful purpose. The Japanese war is still with us, and the rejoicings at the end of the German war were tempered by a sober realisation of tasks still to be undertaken.

The times generate no mood of wild gaiety in which a rosy future can be assumed and all responsibility for its creation is set aside. In its place there is a realisation that nothing worth while can come without effort, and that there are severe problems still to be solved. Enough has been written about reconstruction to make the statement that it must use all the available material and human resources of science almost a platitude. The other side of the question is concerned with future world security. What are we to feel in this matter? Are we going to assume that this has been another war to end wars—to be followed perhaps by another peace to end peace—or are we to try to overcome our natural tendency to a complete revulsion from war and everything connected with it, and begin to think about practical action to deal with the problem?

We look to the outcome of the San Francisco conference to provide us with the political machinery for the maintenance of world peace in the future, and there seems every hope and promise that the machinery will be better constructed than was the League of Nations. But the existence of machinery is, in itself, insufficient. The will to work that machinery at the right time derives in the end from the will of the common man, or, to put at a slightly lower level, from what the politicians in power regard as the probable will of the common man.

It follows that the efficacy of plans for world peace will depend to a very considerable extent on the ability and willingness of the general mass of the people to work these plans. Consequently, any widespread feeling that war can be averted just by dismissing it completely from the mind is dangerous. We have in the past seen manifestations of the effects of this attitude in, for example, the famous Peace Ballot, which expressed an overwhelming desire for peace, but which unfortunately was coupled with a certain degree of confusion over the material requirements for its maintenance. It is, of course, very easy to be much wiser long after the event than one was at the time, and, without foreknowledge and surrounded by a considerable confusion of contemporary events, it was perhaps understandable that a strong feeling rather than a strictly rational assessment of events should have then been expressed. Clearly this topic is a most controversial one, on which it is rash to make general assertions, but it does seem safe to say that the logical consequences of the desire for peace had not been fully and universally thought out, and that the appearance of this fact had a considerable effect on the attitude of the government of the day.

This is now past history, but none the less instructive for that, and its lesson seems to be that we should seek to prepare our own minds as individuals for the realisation that dangers may once more arise and will have to be eliminated by decisive action. Considerations of this kind affect particularly the tenor of public opinion on the scale of the armed forces to be maintained in peace-time.

As usual, there is a specifically scientific aspect to these problems, on which the scientist has a special contribution of opinion to make. Clearly the Services will have to continue their scientific departments for the production and development of new weapons and techniques, and it seems certain that they will do so on a scale considerably greater than before the war. This fact may arouse a feeling of revulsion in the general public. "Are we," one can imagine their saying, "to have new weapons and new means of destruction worse than the flying bomb, the rocket and the dive bomber? What becomes of all the protestations of the scientist that his greatest desire is to promote human welfare, when we find him advocating the development of new and more terrible weapons of destruction?" We are, as always, dependent on the outcome of political action, and our hope that these new weapons will rust to pieces unused can only fail for political reasons. It must be stressed, however, that our security can never be menaced by the existence of the most ingenious of weapons, but only by the growth of the will to use

them. If that will should again become dominant, then the existence of the weapons will be our safeguard.

Although the post-war establishment of the research departments of the Services is likely to be large, it cannot be on the same scale as it has been during the war. A very large number of scientists have been employed directly by government departments during the last five and a half years and have gained a considerable experience in war research. In view of the necessity of maintaining military scientific establishments in peace-time, it would seem desirable to preserve this connection between scientists and the military establishments. The way in which this might be done would be to create a Scientific Reserve comparable to the reserves in the fighting services. Annual refresher courses, lasting perhaps a fortnight or a month and held at government scientific centres, together with the issue, under suitable security precautions, of short bulletins describing progress would keep the members of the general body of scientists in fairly close touch with the department to which they would probably be called in an emergency. The details of such a scheme would have to be worked out with some care, particular regard being paid to the problem of censorship inevitably associated with any security considerations involved. We have become so accustomed to the existence of censorship that it is with some little difficulty that the mind is carried back to the pre-war days when any kind of censorship was anathema. We do not want by the introduction of a Scientific Reserve to tie scientists into a closely woven net of national commitments which would destroy the international comity of science which has rightly been regarded as of such prime importance in the past. The danger of this development of scientific nationalism must be avoided, but there is another aspect of scientific nationalism which becomes involved. The part-time service of all scientists would, even if the armament industries are not taken over completely by the State, operate towards breaking down the exclusive ownership of technical secrets by particular firms, secrets which, in the past, have been sold to potential enemies. It is almost inevitable that the creation of a Scientific Reserve should carry with it a reciprocal revelation of secrets and should involve, not only the personnel, but also the laboratories in which they are normally employed. Without practical organisational experience, it seems impossible to determine the best way of securing this, but one method could, for example, be to grant the right of inspection to all laboratories in which members of the Scientific Reserve are normally employed, and the right to demand a full disclosure to the government of any process, details of which have not been given in a public journal.

The establishment of some such system would seem to be an essential part of the post-war machinery for national defence, and a considerable measure of control should be vested, by as democratic a method as possible, in the scientific profession itself. For their part, the scientists should support such a scheme and should resist in themselves any tendency to abhor it because of its warlike connections.

National Health Service

On April 26 a discussion took place in the House on the proposals for a National Health Service. Dr. Edith Summerskill raised the question on the motion for adjournment, and expressed herself very dissatisfied with the modifications of the original White Paper proposals which were being discussed by the British Medical Association. Mr. Willink appeared to disclaim any responsibility for these discussions which, he explained, could bind neither the Cabinet nor the House, nor were they to be regarded as more than a democratic expression of medical opinion.

It is correct that all interested parties should have an opportunity of putting their point of view before any new legislation is passed, and no doubt it can be claimed that this is what is being done here. However, there is also the question of satisfying the public at large, and one must give consideration to the impression it is likely to form about any unilateral negotiations, however democratic the guise in which they appear. The public quite definitely want a satisfactory national health service, and it is open to doubt whether they are anything like so tender-minded about such matters as the free choice of doctor—have they, in fact, got it now—as it has been found expedient to represent them to be. It is also clear that there is a very widespread public suspicion that the medical profession intends to stick like glue to its ancient privileges. This may be the ignorance of the lay mind—or perhaps, who knows, the sturdy commonsense of the common man—but the fact is that the suspicion exists. It must be confessed that there are times when even the most sympathetic of citizens gains, perhaps wrongly, the impression that there is less concern for the public welfare on the part of certain influential sections of the medical profession than there ought to be, and a good deal too much concern with the maintenance of a position of special privilege. If this impression is incorrect, the medical profession ought, in fairness to its own reputation, to take steps to refute it, both by word and if necessary by action.

The official report of the debate gives the impression that Dr. Summerskill's remarks were received with little sympathy by the Minister, who entrenched himself behind a barricade of counter-accusation of using violent language and of being ignorant of the White Paper proposals. In spite of this it is felt that the general sympathy of the country will be with the lady, and even if she did express herself in a manner calculated to irritate Mr. Willink, she did make the protest which the public wants to make. They feel that private negotiations have been going on to discover what the medical profession will accept, and that all the concessions have been made by Mr. Willink. They can see their health centres, whose worth has surely been proved beyond doubt by the Peckham experiment, disappearing rapidly to leave behind, as vestigial organs of a great project, only a few experimental centres. They see the old two-class medical system of payment—Harley Street service by the well-to-do and panel practice for the poor—remaining firmly entrenched for many years to come. They see the old mercenary troubles of the selling of practices and capitation payment for panel work going unremedied, and they foresee that medical attention will continue as a saleable commodity instead of becoming a public right.

Perhaps Dr. Summerskill did use violent language, and perhaps she did make herself a nuisance to those who are satisfied with the present state of affairs. The general public wish that more M.Ps. would do the same. It is just at this moment when reconstruction and social ser-

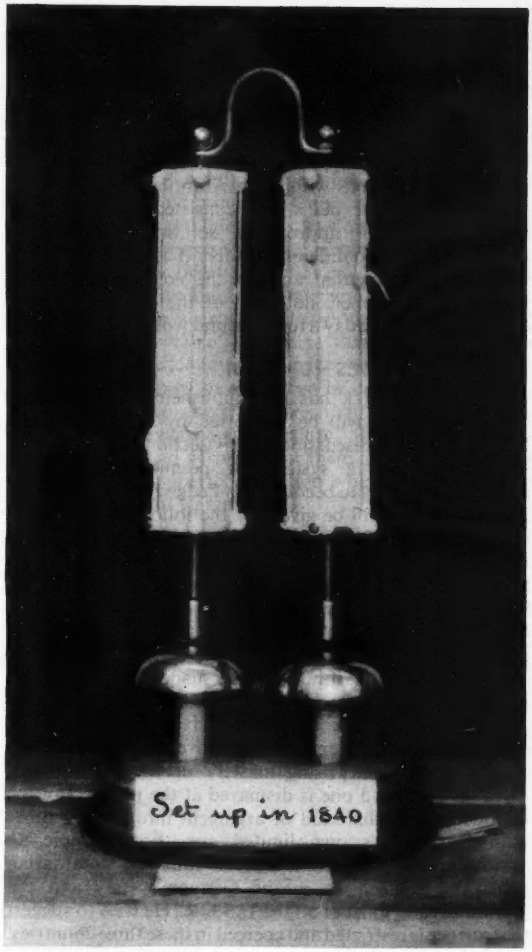
services worthy of the name are endangered that it is right and proper to make a first-class fuss. The prospect that all our cynical reservations about the promised future will be realised is so lamentable that we cannot afford to let it pass without the strongest protest.

Two Centuries of Electricity

In the history of science there are occasionally to be found men whose names are remembered because of their wide knowledge and their capacity for drawing together into a coherent pattern what seem to be isolated and disconnected threads. From such an act of synthesis there may spring many new shoots of scientific growth, some of which eventually become new and separate branches of knowledge. In retrospect, the act of synthesis may seem trivial enough: reading about it many years after, we may have difficulty in distinguishing exactly in what the decisive step consisted, and in viewing what seems to be a smooth flow of discovery we may find it difficult to see how an apparently obvious step could fail to have been taken. The true measure of greatness can only be assessed by an effort of the imagination to reproduce the ignorance and uncertainty which prevailed before the significant step was taken.

A man of this kind was Alessandro Volta, who was born at Como on February 18th, 1745, and who was successively professor at the gymnasium of his native city, professor of physics at Pavia and director of the faculty of natural philosophy at Padua. He retired in 1819 and died in 1827. He was Copley medallist of the Royal Society in 1792; in 1801 he was called to Paris by Napoleon and a medal was struck in his honour.

His work, for which he received these honours and decorations, was of fundamental importance in electrical theory and practice. He followed in the footsteps of Galvani, who in 1780 had discovered that if the nerve of a frog's leg was connected to wires of two different metals, then, when these were joined, the nerve was stimulated, causing the muscle to twitch. Galvani considered that he had discovered "animal electricity" and thought that the presence of the animal tissue of the frog was an essential part of the phenomenon. Volta realised that this was not so, and that the difference of electric potential was associated with the junction between the two metals. It is, however, worth noting that at the time methods for the physical detection of electricity had not advanced very far, and the frog nerve actually provided a relatively sensitive indicator of the passage of a current. Volta went on to demonstrate that electric currents produced by the contact of different metals could cause sensation. For example, a two-limbed metal fork, the limbs being of different metals, produced the sensation of a flash of light when one limb was placed in the mouth and the other brought into contact with the eye. In this sense, Volta must be regarded as one of the pioneers of electrophysiology. However, his work was far more extensive than this, for he succeeded in showing that "galvanism" and electricity were identical. His most famous contribution was the development of the Voltaic pile, and a later development, the *couronne des tasses*, both of importance as sources of electricity in those early days. The pile simply consisted of a series of discs of zinc, copper and paper, the three being laid on top of one another in that



order, with three more discs on top of that, and so on. The paper discs were moistened with brine and the multiplication of the potential difference by the piling up of perhaps hundreds of triads of discs produced quite a useful source of electric potential. (The device is of little value as a practical source of current, for when the ends of the pile are joined the current is small and almost immediately falls to zero, due to the accumulation of bubbles of hydrogen on the plates.)

There is at the Clarendon Laboratory at Oxford an example of a "dry" (Zamboni) pile which is of some interest. It consists of a pair of piles each about an inch in diameter and about five inches high. The outside surfaces are coated with sulphur and it is thought that each must contain something like 2,000 elements. The two upper ends, of opposite electrical polarity, are connected by a wire, while the lower ends of each are connected to a small bell. The whole is supported on non-conducting pillars to insulate it from its surroundings. From a fine thread hangs a pith ball which with a very slight displacement makes contact with one bell or the other. On making

contact with one bell, the pith ball becomes electrically charged and is repelled from the bell on that side, swinging over until it strikes the opposite bell. It then becomes oppositely charged and is repelled until it strikes the first bell again. The pith ball, once set swinging, through a distance which is only a fraction of an inch, will continue ring the bells. The toy, which is dated 1840, has apparently been ringing the bells without interruption ever since.

Volta's *couronne des tasses* consisted of a series of vessels containing appropriate solutions, into which dipped wires of two different metals. These also produced a difference of potential, and like the Voltaic pile, were an important forerunner, not only of the electric cell and battery, but of Faraday's fundamental work on electrolysis.

Dr. Baker does it again.

DR. JOHN R. BAKER has just published another book.* Some parts of it will be supported by many scientists: for example, the discussion on vivisection on p. 107 and his advocacy of a system for permitting laboratory assistants of ability to become fully fledged scientists (p. 93). Hearty support will be given for the following sentiments expressed on p. 99: "In a democracy, legislation depends ultimately on the opinion of the people as a whole. It is therefore desirable that they should form their opinions by considering valid arguments based on a truthful presentation of facts. It is my purpose to suggest that the scientist's love of truth could be harnessed to the common welfare of mankind, if he could persuade others to use his own method of argument in the political sphere."

If only Dr. Baker could have lived up to his own standards. For a scientist with a love of truth he shows in this book a surprising mastery of the technique of *suggestio falsi*, and one is dismayed at the prospect of the introduction of this kind of argument into spheres other than Dr. Baker's own limited one. For example, in various places he discusses what he calls the "totalitarian states", by which he means Germany, Italy and the U.S.S.R.—and most of all the U.S.S.R. He tries to suggest that science is restricted and coerced in these three countries, particularly the last, by quoting on p. 38 a number of Nazi pronouncements on science as an indication of what happens in totalitarian countries.

On the subject of the planning of science he has fixed ideas. He reiterates a belief in the predominant effect of chance in scientific discovery; he sets up an idea of scientific freedom which does not exist in practice anywhere except in restricted university circles: he knocks down an Aunt Sally of his own creation, which is a preposterous caricature of what is meant by planned science. All the old red herrings are dragged across our path: he talks of planning resulting in coercion from above in scientific work (it is clear that he is not aware that such coercion does exist in industry, and that the "planners" want to get rid of it as far as possible). He postulates the destruction of initiative by any form of planning or oganised team work: he asserts that in the name of avoiding useless duplication, the "planners" would eliminate independent checking of experimental results.

Let us put the matter in simple language. First: planning of science means that a general guiding programme of work shall be *agreed* by mutual consent of *scientists* working in a particular field, so as to ensure that the ground is properly covered. Second: such a plan shall be directive and not coercive; if someone wants to duplicate a piece of work he is at liberty to do so, but he will be aware that he is duplicating. Third: independent determinations of certain natural properties or constants are obviously most desirable, but there are other problems on which common agreement could easily be secured and here duplication would be of little or no value. Fourth: common discussion of problems by *all* the workers in a team is likely to evoke valuable contributions from any member capable of giving them; teams already exist which are run on these lines and are found to work well. Fifth: in physics particularly (for instance, in research concerned with low temperature and nuclear physics) teams are essential and no progress at all can be made without them; for many years planned research has existed in this and other fields, sometimes on the laboratory scale (e.g. the Leiden Low Temperature Laboratory) and sometimes on the international scale (e.g. the determination of solar parallax). Sixth: plans must be flexible, and the discovery of a valuable line of investigation should be followed by a diversion of effort in that direction. Seventh: team work should be adopted in investigations suited to it; personnel and problems suited to individual work should be left alone but should receive adequate support for their work.

Dr. Baker knocks his nail into the coffin of planned research by citing a number of examples, but he is no expert with a hammer nor is he very good at selecting nails that are not crooked. His chief example is penicillin, some of whose properties were first discovered by accident. The deduction which he draws is by no means the only one possible. Penicillin was in fact discovered accidentally, but it would have remained as a laboratory curiosity if the team of workers at the School of Pathology at Oxford had not been working on a systematic investigation of antibacterial substances. To suggest that the initial discovery contained all the pure research, while all that has followed is development work (this is the impression given at one point in the book) is pure nonsense.

Again, on p. 80 Dr. Baker cites a list of 27 crucial advances in science made between the two wars and points out that none of them refers to work done in the U.S.S.R. As he leaves out the low-temperature work done both in the U.S.S.R. and elsewhere, the work on gas-equilibria done at Kharkov and the Soviet work on genetics (more of this presently) one can hardly feel that this is much of an indictment against Soviet science. Of the examples he cites, at least four pieces have been due to supporters of planning while only one comes from his small but oft-quoted group of anti-planners. At least a third of his examples are actually classic instances of planned research.

Dr. Baker is rabidly anti-Russian and develops a part of his attack on Russian science around the genetics controversy in the U.S.S.R., an attack which he illustrates by quotations. One is naturally doubtful of the value to be placed on isolated quotation from a difficult foreign language, and there is much reason to recommend Professor Bernal's opinion that this controversy has been magnified out of all proportion on account of the scanty details published outside the Soviet Union. What does impress the vast majority of scientists is the quite remarkable progress in the applications of vernalisation and other

* *Science and the Planned State*, Allen & Unwin; 7*s*. 6*d*.

agricultural techniques, which has been made in the Soviet Union, and it is little more than a quibble to say that this is technology and not science. If Dr. Baker is correct, then we are all, including Dr. Baker himself, technologists and not scientists.

Dr. Baker's general attitude to science is well illustrated by a quotation from p. 41: "Let it be clear that freedom of inquiry does not and cannot mean perfect freedom. . . . Similarly, scarcely anyone is free to have a cyclotron or an ultra-centrifuge at his disposal unless he can make other people believe that his use of such an expensive instrument would result in important advances in science. An enormous amount of scientific work can be done, however, with little expenditure, and in so far as his imagination directs him towards relatively inexpensive studies, the established research worker in a British university is generally remarkably free."

The implications of these remarks show clearly to the thoughtful reader the basis of Dr. Baker's philosophy, and they likewise give away the whole of his case. But to a superficial reader this book is a positive invitation to help rebuild the poverty-stricken sealingwax-and-string school of science. Three other sentences summarise equally well Dr. Baker's general outlook on life as revealed in his book: "The community, then, should not thoughtlessly demand extra services of the scientist" (p. 86): with reference to intellectuals in general, "honour should be accorded to these exceptional men and women, and to those who make an environment in home, school, or university in which genius and talent can develop and flourish"; and "Nevertheless, it seems that the common man has not an urgent desire for liberty of action, and is prepared to use the vote granted to him by liberal-minded people to destroy not only his own liberty, but that of uncommon people as well. It is impossible to imagine that the common man understands the conditions under which great work in science, philosophy, or music can be done; he is prepared and actively encouraged to think that the only thing that matters is his own material welfare" (both p. 104).

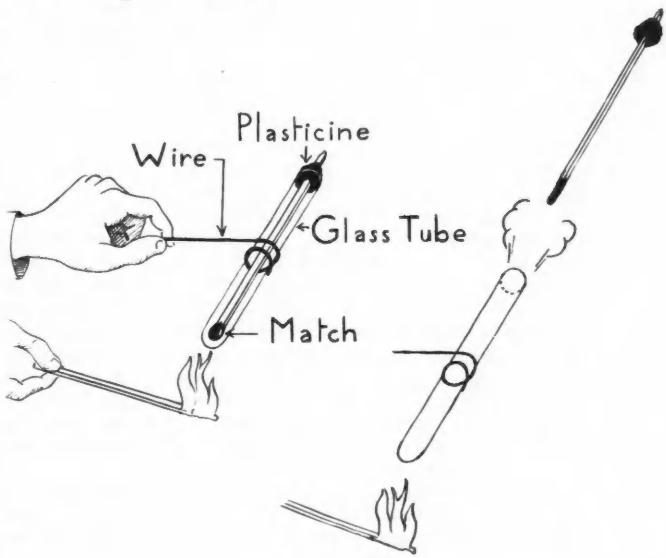
It is perhaps no surprise that there are few who accord Dr. Baker that superior valuation which he is apparently prepared to grant to himself.

JUNIOR SCIENCE

Firing a Gun

IN a petrol engine or a modern steam engine the expansion of a gas with which we had filled beforehand, the cylinder of the engine is made to do work. This idea of an expanding gas, however, is not the same one which led to the development of the earliest steam engines. These machines relied for their functioning on a quite different process—the change of water into steam. When this change is effected, as for instance in a kettle boiling on the fire, the lid of the kettle will be lifted by the evaporated steam because water in the form of steam takes up a much larger space at the same temperature than in its liquid form. The early steam engines included a cylinder in the bottom of which water was boiled, as in a kettle; in place of the kettle lid was a close-fitting piston which was pushed out by the steam. Once the engine had done one stroke, the steam had to be condensed by a spray of water to get the piston back into its original position.

This process of doing work not by the expansion of a gas but by changing a liquid or a solid into a gas has influenced history not only because it led to the invention of the steam engine but, perhaps even more important, because it brought us the invention of the gun. Strange as this may seem, in its construction and method of working a gun is practically identical with the early steam engine. The gun barrel forms the cylinder and the bullet is the piston. Instead of generating vapour by boiling water in the cylinder, gas is generated in the gun barrel by burning an explosive charge; that is, a mixture of chemicals which when ignited will undergo a reaction in which large amounts of gas are liberated. In fact the construction of the gun pointed the way to the modern steam engine and the petrol motor because the chemical reaction of the explosive charge not only liberates gas but also heats up the liberated gas and thus combines the work done by the liberation and by the thermal expansion of a gas.



You can yourself construct a harmless little gun on which you can study the effect of a gas liberated by an explosion. Take a small glass tube (pyrex if you can get it) which is closed on one end and put a Swan match into it, head downwards. Plug up the aperture with plasticine and heat the end of the glass tube which contains the match head. The match head will explode and the liberated gases will drive the match out of the "gun".

K. M.

Before they could make their attempt at world conquest the Nazis had to destroy the discipline and restraints of civilisation within their own country. To a high degree they succeeded in that more immediate aim of training as many Germans as possible into the way of 20th century barbarism. The task of re-educating Nazi Germany seems so important that it somewhat overshadows a far more deserving case—the urgent need to rehabilitate science and learning in those occupied countries where the Nazis tried systematically and ruthlessly to destroy the native culture by murdering or imprisoning the scientists and other intellecturals, by looting and wrecking the physical centres of learning. Our Allies have first claim upon our assistance so far as it is in our power to help to rehabilitate science teaching and research in the continental countries. In this article Dr. E. F. Armstrong discusses what must be done in this direction. He also argues the need to prevent German *Kultur* ever again exerting an influence beyond its true worth. Dr. Armstrong is specially qualified to talk about the rehabilitation of European science, as for many months now he has been chairman of the commission set up by the Conference of Allied Ministers of Education in Britain to deal with the supply of scientific equipment to the schools and universities of the liberated countries.

THE NEW EUROPE: Culture or Kultur?

E. F. ARMSTRONG, F.R.S.

Europe has been liberated; for six long years Germany has done her worst both physically and mentally to degrade the stricken peoples of a whole continent. She has imposed her *Kultur* by force, a sequel to the insidious and clever propaganda that has been going on for seventy odd years. What have we to offer Europe instead to help her to recover mentally? Can we not introduce British and Allied culture, and oust for ever the dependence on Germany, the belief that in science and often in literature the German way was best? The opportunity is unique, it may never return, we should seize it with all our might.

What is culture as we understand it? The Oxford Dictionary terms it the intellectual side of civilisation, defining this as to bring out of a state of barbarism, to instruct in the arts of life, to enlighten and refine. Matthew Arnold calls culture the acquainting ourselves with the best that has been said and known in the world.

The individual mind is active on a constant succession of more or less connected images, which images characterise our mental quality. The need is to place before the minds of Europe images that will represent Allied thought and not German propaganda.

It is not generally realised perhaps how difficult the position is that has resulted from the Nazis' forceful educational propaganda among teachers and in schools, especially in the German-speaking areas of Europe. Young people growing up to be the students of the near future have had the most pernicious doctrines instilled into their minds and will require special treatment in their future education: the old pre-war methods will not suffice.

In all of us the young, effervescent ideas acquired in youth were based on emotionalism and wishful thinking. As we progress the ideas gained in youth are altered by the flow of human experience and the greater knowledge which maturity provides. Our ideas are not exclusively our own: in them there is the ever-present influence of all the great authors whose works we have read and which have become an automatic part of our thinking, indelibly impressed on our minds. Formation or culture requires more time, more love, with an admixture of criticism and humility which is more easily discovered through experience than defined in words. The way is clear, we have to help the youth of Europe who have been subject to Nazi influence, to get them puzzled and stirred up to find out more. We must help them to search for greater truth and change the concept of their lives.

The way at first lies along the paths of literary education, but science can be introduced at a very early stage, particularly technical science which is often closely connected with the means of a livelihood.

So far reference has been made to culture in the widest sense of the term. Our concern here, however, is primarily with scientific culture. It appears still necessary to stake a claim for science as a cultural subject. One is regarded as a barbarian if a split infinitive is used but there is no stain on the character of a man unable to distinguish acid from alkali. The tradition of the schools that only classics count dies hard; so long as it persists Britain will fall behind in the race for existence in a technical world. Most scientists have a clear idea of what scientific culture means, it should of course be based on literary culture: there is no need to elaborate the subject further.

Let us consider some illustrative facts from my own science—chemistry: the deductions that one can base upon such facts are largely true of all the sciences. In chemistry we have gone far from the day when the subject was defined as a French science founded by Lavoisier. That time was followed by a long period of worship of Germany—justified in those early days when it was based on genuine scholarship and achievement and not on propaganda.

Liebig began it when he made chemistry, especially organic chemistry, a subject of practical research at the laboratory bench. His magnetic influence drew our young men to Giessen. London realised the need to do the same and largely thanks to the energy of the Prince Consort, then the active President of the Royal Society of Arts, Hoffman came to London to start the Royal College of Chemistry. Here the atmosphere was one of intense research activity—able young Germans came to London, their British counterparts continued their research work at German universities. Hoffman went back to Germany in 1864; Edward Frankland succeeded him, and the tradition of working in Germany continued. Inspired by Norman Lockyer, the 1851 Commissioners sent most of their scholars to Germany and up to 1900 the pick of our future chemists finished abroad. There were a few notable exceptions, W. J. Pope and T. M. Lowry in particular.

The Germans used the money exacted from the French after 1870 largely for the purpose of increasing educational facilities. Research made an appeal to the orderly German mind, whilst the developing dye and other chemical industries provided employment for the graduates. Bit by

bit the machine was built up—a great volume of research work, particularly in organic chemistry, poured out from the research laboratories. It brought as a corollary journals for its publication and text books, as well as the development of an industry providing laboratory apparatus and chemicals. The names of Kahlbaum and Merck became household words, they served their customers well. Students from all countries flocked to Germany where "Lehr und Lern Freiheit" prevailed into the twentieth century. They each took back home an unconscious dependence on German supplies and literature. Laboratories like that of von Beyer in Munich and Emil Fischer in Berlin were international. There was great competition to work under the Professor and he thus enjoyed the help of the most able and best experimental workers to the advantage of the speed and quality of the research work.

Midway through the first decade of the twentieth century the position began to deteriorate—the German became more aggressive, the military party gained power and carried the industrialists with them, the peaceful academic atmosphere almost reminescent of the middle ages in the smaller universities was vanishing.

There were stirrings in England to revive our chemical teaching, our students were doing research at home and an increasing volume of first-class work was coming out of the universities. Only the chemical industry lagged behind, kept under by German competition. Far too few industrial firms employed a chemist.

The 1914–18 war gave both Britain and America a jolt. The story of how quickly and how effectively we improvised is well known. Between wars we have seen a renaissance in Chemical Science in both allied countries, coupled with a growing intolerance of the German hegemony. America at the beginning owed much to Charles Herty, a great and patriotic Southerner.

German control of scientific apparatus

But Britain failed in one respect—no real effort was made to create a scientific apparatus industry, which remained entirely in German hands. America was more far-sighted and by 1940 had become largely independent of Europe. The reasons for the difference are worth examination. America was further away, the development of research and of the use of instruments in industry, particularly the rapidly developing modern oil-refining industry, made very much larger demands on home manufacturers with its effect on semi-mass production and cost. The American is naturally a salesman. Here in England we were close to the continent, our prices were not competitive, delivery times bad, outputs small, salesmanship poor. The research worker was not concerned with patriotism, he wanted quick delivery of apparatus at the lowest price and the German competitor took full advantage of the position.

The story as related here applies to chemistry, but the facts and the deductions are largely true elsewhere in science.

If England with all her independence fell for German science and its impedimenta it is obvious that Europe, excepting perhaps France, would become a complete victim. University professors, staff and students with few exceptions reflected German mentality, read German books and journals, bought apparatus from German catalogues, and listened to German salesmen. *Kultur* had penetrated every branch of science everywhere in Europe. The propaganda value was enormous—and it kept on growing as the number of scientific workers increased. European students were trained in an atmosphere of Germanism, they read little, if any, Anglo-Saxon literature and were largely ignorant of our current work, as is shown by the fact that it is so little quoted in their published papers.

FIG. 1.—The high traditions of German science used to attract countless foreign students to her universities. The Nazis finished that. Here is Professor Johannes Stark, who once won a Nobel Prize for his physical researches but who later gained greater fame as a spokesman of Nazi "science". "To purge science from its Jewish spirit is our most urgent task," was one of his pre-war dicta.

So far we have traced the logical and inevitable development of the German stranglehold on European science. Germany has sold Europe at least £100,000,000 worth of scientific apparatus in recent years, a production which has fostered the development of strong and established scientific industries.

It is easy to say it must not happen again, but such a statement involves the obligation to take certain constructive steps both to rebuild the shattered and destroyed educational life of our European allies and to give them access to supplies so that they have no excuse to return to Germany for these.

Scientists need to travel

It is worth while to consider some of these constructive steps in some detail. But first it must be made abundantly clear to our European colleagues that Britain is devoting much of her effort upon the war against Japan. It is still hard to find labour or materials for other purposes.

The first approach to the problem must be the personal one. Britain has been glad to give hospitality during these grim years to many European scientists, who have doubtless learnt much of our way, perhaps of our strength as well as of our failings, have made personal friendships and will return home as pioneers of Allied scientific culture. The Club House of the Society of Visiting Scientists in Old

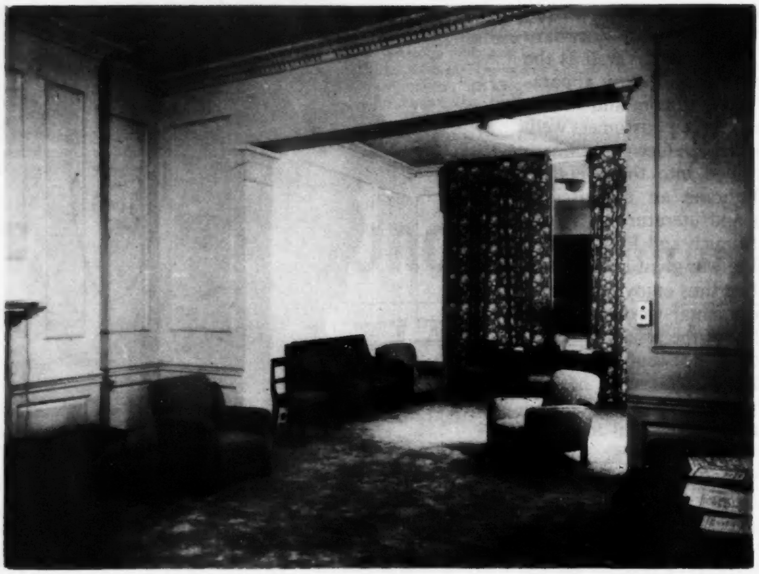


FIG. 2.—The comfortable lounge at the headquarters of the Society for Visiting Scientists in Old Burlington Street, London. The British Council, in consultation with the Royal Society, was responsible for the foundation last year of this society, the aim of which is to provide a meeting place and information centre for foreign scientists visiting this country. This is the first centre of its kind in Britain. The affairs of the Society are controlled by a committee that includes representatives of many European countries.

Burlington Street is making a contribution to this cause; it should be maintained for many years to come and provide a starting point for very many foreign scientists in the future to make British contacts. There have been several such efforts to make our visitors feel at home. Perhaps we have been too busy to show them as much of our institutions and academic life as we could have wished, but at least they have seen us at work on the common cause of civilisation. But we want to attract every Continental scientist over here, young or old. Some means must be found to give them a term or more at our universities or at least a holiday course. Research students must be welcomed to our laboratories during the period, long or short, that will elapse before facilities become available in their own countries. Europe must make English the second language —more of us must learn a foreign language.

I should also like to see the International Committees of the Royal Society seriously discuss this subject with the intention of devising means to quicken continual intercourse between England and Europe by a far more simple means than the cumbersome International Congresses which largely fail because large delegations from a country tend to keep together and omit to mix with their hosts.

Export of scientific literature

Next to the spoken comes the written word. English and American journals should circulate widely on the Continent. For instance, the journal of the Society of Chemical Industry should cease to be parochial and aim to carry up to date information of wide interest. It should be subsidised by the Chemical Council so that many free copies could go to European University Libraries. The British Council might even consider extending the scope of *Monthly Science News* and giving it wide European free circulation: something like the "news letter" of the American Chemical Society seems indicated, some organ able to receive Continental information and publish it in French if desired. Once this first step in reading English had been taken, workers at the European universities would be ready to read British and American scientific and technical journals and would discover how advanced we are, equal, if not superior to the Germans in the quality and novelty of the work in each and every branch of science.

Concurrently British or American text books might be accepted, either in the original or translated, as providing for all the needs of the student and fully replacing all German books. The same applies to the standard books of reference essential in every science.

In the same army of Allied literary invasion would come the trade catalogues and price lists of technical industrial firms, both in English and in the language of the country, showing what we had to offer. To sell apparatus to the continent there will be needed technical travellers with language qualifications and a follow-up system of service such as any efficient industry should and indeed must give to-day if it is to be successful. Admittedly travellers and service are costly unless the volume of trade is big enough to carry it. In our opinion the business is there, industry must be bold enough to go after it, the foreigner must be pledged to give us first refusal of it and not to buy either direct from Germany or through camouflaged German firms in neutral countries.

We now come to the vexed question of the supply of scientific equipment to the Continent. The problem is not an easy one: indeed it probably requires action on a high ministerial level if it is to be straightened out. The British pre-war industry was small; much of the demand was satisfied from Germany. The American industry was several times larger, it was expanding and could meet

FIG. 3.—A meeting, held in the Ministry of Education building in London, of the Conference of Allied Ministers of Education. At the time this photograph was taken the Rt. Hon. R. A. Butler presided over the conference; other members then were :—(*left to right, back row*) Prof. Vaucher (France), M. Milosh Trifunovitch (Yugoslavia), Prof. Rene Cassin (France), M. Juraj Slavik (Czechoslovakia), M. Aghnides (Greece), General Haller (Poland), M. Bolkestein (Holland): (*left to right, front row*) Mr. R. Seymour, Mr. J. W. Parker, Dr. A. Sommerfelt (Norway), Dr. Sulimirski (Poland), Dr. Subotic (Yugoslavia), M. Hoste (Belgium), M. Hjelmtveit (Norway).

German competition. It is not always realised how much is covered by the term scientific equipment. Starting with the simple apparatus and materials required in schools it includes all that is required in teaching and research in chemistry, physics, biology, geology, medicine as well as the larger apparatus needed in engineering and trade schools. Much of it is precision apparatus, often of very great accuracy. It includes glass, ceramics, metal, plastics and chemicals. Our war effort has been stupendous but it has not covered all the items which will be wanted when peace comes.

At home the requirements then will tax the full capcity of the manufacturers. The accumulated demands of six years from schools and colleges and universities and all other research laboratories have to be met. The Education Act will bring new orders, so will the very much greater extension of research by industry, so also will the expansion of research in the colonies and there will be other calls. All this means full capcity work for the industry or at least most of its branches for years, work for which the customers have money to pay.

How is the Continental demand to be fitted in, particularly for those countries whose Governments have no funds available? It has been already said that a fairly close estimate of the total equipment in all sciences required for the continental teaching institutions of all grades amounts to not less than £100,000,000 at pre-war prices. Some of this has been destroyed, some has been looted; all of it is six years old and perhaps not well cared for and therefore in need of replacement or at least modernisation.

No doubt some of the apparatus required will be made in the respective countries—e.g. glass in Czechoslovakia—and the establishment of such manufactures should receive every encouragement. But the bulk must come from England and America.

Now in our view the rehabilitation of educational scientific institutions in liberated countries cannot wait. It must be carried out by the Allied scientific equipment industries in order to free the liberated countries from German scientific dominion.

It would appear essential that the liberated countries should receive a priority quota of all scientific apparatus made and available. Such action puts the matter on the highest political and economic plane and demands the attention of the supreme Allied political and economic authorities. It will be necessary to initiate special measures of organisation in the relevant industries and give both direction and support to the work on the highest level. Perhaps at the same time there might be established a central authoritative body with the highest political support permanently to act as a focus for all inter-allied scientific relations.

Talleyrand's recipe for success was to have a hard heart and a good digestion. But in this instance we can claim we were not sent into the world to be happy but to do right. Every man of science will wish to see European science put on its feet, a science totally free from Nazi taint, breathing the free air of Anglo-Saxon ideals.

There has been in existence in London for a considerable time a Conference of the Allied Ministers of Education presided over by the Rt. Hon. R. A. Butler, Minister of

Education in the National Government. This has an active Executive Committee working through a Book Commission, a Scientific Commission and others. It concerns itself with the cultural rehabilitation of the liberated countries and the diverse and acute problems of providing every form of education for children and students. The teaching of science is only a section of the problem but it is as true for science as for education of all sorts that unless supplies are made available the resumption of educational activities will be greatly delayed and additional hardship for all will result.

At a meeting of the Conference early in March, Mr. Butler was in a position to state that considerable progress had been made towards the establishment of a United Nations organisation for educational and cultural reconstruction. This question is being brought up at the San Francisco meetings out of which a final constitution of the new organisation will emerge.

It is essential that the activities of this body include adequate attention to the scientific aspects which are always likely to be overlooked on such occasions since men of science are not present among the delegates. (It cannot be too often reiterated that the future world will be a technical one, with a need for the maximum knowledge of every science widely dispersed among the people.)

The idea and ideal of a central authoritative scientific body needs developing with all possible speed and authority as part, no doubt, of a general organisation, but autonomous and separate. It must have the full official support of the British, the United States and all the other Allied Governments, but it will flourish best if left largely to manage itself: it will necessarily be concerned with pure and applied science at all educational levels. It should be possible for such a body to promote something better in the future than the unwieldy International Congresses that took place in the pre-war period. They were swamped by too many delegates from some nations present mainly for the purpose of propaganda and often the wrong people, not the workers, presided over them and their sections. Little or no serious work was accomplished.

It seems that what is wanted is meetings like those held at the Solvay Institute in Brussels so genially presided over by Sir William Pope at which not more than twenty, or at the most thirty delegates were present; they were in close contact with one another for a few days and discussed a limited range of pre-arranged subjects at set sessions. Those present got to know each other under the best possible conditions and much good resulted.

A large number of such meetings concerning different sciences could be held in the course of the year in diverse centres; there should be a central fund from which a contribution could be made to delegates' expenses, so enabling the younger men to attend.

Whilst it is desirable that Governments as such give maximum recognition to and adequate support of science, care must be taken to prevent scientific problems being regimented. There are international organisations concerned with science whose conduct is arbitrary and opposed to the spirit of true science. If we are foolish enough to give up our freedom for money or political support then scientific progress is doomed.

In our earlier remarks we have taken it as our first task to bring Anglo-American scientific culture to the succour of our European allies. This is undoubtedly the correct attitude, but it does not mean that the effort and effect should not be reciprocal, namely that we should at the same time receive and learn from them culturally. The outstanding task—a very real one—is to oust the German *Kultur*. The formation of international links such as those indicated will follow by stages, all the better for being tentative and experimental and so tested and tempered by experience. The first effort of Allied scientists, of whatever nation, should be to rehabilitate science in Europe; the second might well be to build up such understanding and friendship between one another that we could have the same thoughts and speak with one voice on the bigger or more ethical matters. Co-operation on official and Government levels will be a third stage, more formal and influenced by political considerations and therefore of less concern to those in the front line of scientific research and education.

German Scientific Instruments

SINCE the above article was written, the following letter appeared in *The Times* for 5 June over the signature of Mr. F. Wakeham, President of the Scientific Instrument Manufactures Association of Great Britain.

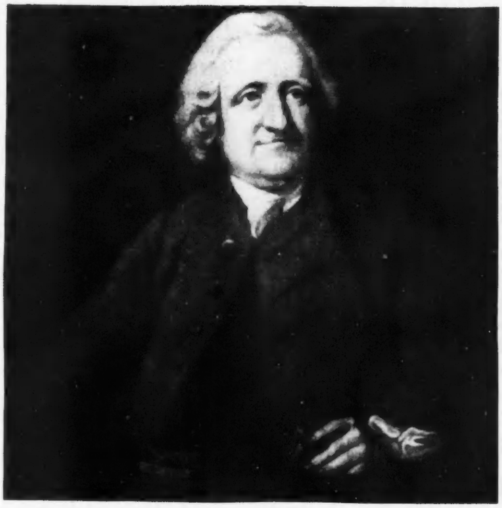
"We were astounded to read in the contemporary Press that encouragement is being given to continue the production of optical glass and scientific instruments in Germany, and that 6,500 workpeople are engaged in carrying out this work under American supervision. The part played by scientific instruments during the war is universally agreed to have been decisive, and the industry has had so much "lip service" from every quarter on its great achievements, and the need for maintaining its high standard during the peace years, that it feels that to encourage Germany to maintain, even temporarily, an optical and scientific instrument industry, and thereby retain one of the most important activities for the prosecution of war is suicidal policy. It will be to the interest of the world, and particularly the British Empire and America, if the production of optical glass in Germany is forbidden. Optical glass at least equal in every way to the German glass can be obtained from these two nations more than enough to supply the world's requirements.

"Germany has consistently subsidised and used worldwide propaganda to make the world think that her scientific instrument industry is in advance of any other country, because she knows, as everyone who has studied the subject must know, that the country which can keep its scientific instrument industry in a healthy condition has the means to be aggressive or to fight aggression. The members of the Scientific Instrument Manufacturers Association of Great Britain, which comprises 75 firms and employs more than 50,000 people, are unanimously of the opinion that the instrument industry in Germany should be prevented from being again in a position to dominate the rest of the world, in peace or in war."

The Rise of British Optical Glass

M. SCHOFIELD, M.A., B.Sc., F.R.I.C.

WAR-TIME developments providing optical glass for the cameras, range-finders, binoculars and other instruments used by our armed forces are but a fitting conclusion to the rise of British optical glass resulting from the pioneer researches of a number of workers. Too much tribute has been accorded to names like Carl Zeiss; too little is heard of Dollond, Vernon Harcourt, Hall and Bontemps who laid the foundations of optical glass developments in our own country. It is true that men like Zeiss had considerable success in this field of enterprise, which became almost a monopoly—so much so that it became the fashion to believe that no other products could possibly equal those of this man of Jena. It is true also that Zeiss had brilliant support in his business venture from German scientists and glass-makers ; men like Otto Schott, that glass-worker who first stirred his molten masses with the stems of churchwarden pipes, or like Ernst Abbe (1840-1905) whom Zeiss called in as the genius who could prepare different glasses for camera lenses and microscope lenses and who conjured forth the Abbe condenser, the Abbe immersion objective, the Abbe apertometer and other fruits of a fertile brain. But now that new British optical glasses challenge competition from any others, a review of optical glass developments in this country shows that Britain holds a worthy place in such history.



John Dolland, F.R.S.

Two contemporaries, Chester Moore Hall and John Dollond, were pioneers in the efforts made to overcome chromatic aberration in lenses. Hall was neither glass manufacturer nor optician, but an Essex landowner who had studied at the Inner Temple. From a study of the human eye he became convinced that an achromatic combination of lenses should be possible by use of crown and flint glasses. Hall is credited with the discovery of the achromatic telescope, but his instrument suffered from lack of homogenity in the lenses due to the fact that the stirring method for treating molten glass had not yet appeared. John Dollond (1706-1761) furnishes probably the only example of optical glass history benefiting from an influence which served other industries (cut glass manufacture, for example) so well—the influx into Britain of refugees from religious or other persecution on the Continent. For Dollond's name probably derived from D'Hollande, the man himself being a descendant of Huguenot parent refugees who came to be weavers in Spitalfields. His son Peter had set up an optician's business, and, after some years during which he curtailed his sleep in order to study optics and astronomy, the father joined the venture to bring considerable skill and knowledge to it.

Round about two centuries ago the idea of colour correction in telescopes was attracting attention. For example, in 1747 Euler in his *Berlin Memoirs* proposed systems of lenses and water sive powers. Newton seemed to provide two varying disper- to have given up the idea of being able to attain achromatic combinations by systems of several lenses. Dollond was more optimistic, however. In the paper he gave to the Royal Society in 1758 he described, in an "Account of some experiments concerning different Refrangibilities of Light", what we now know as the principle of the direct-vision spectroscope. About that time he was also at work on the opposite effect, striving to obtain refraction without dispersion or colour. Dollond ground his wedges of flint and crown in this effort to overcome chromatic aberration, for it was well known that lenses of short radius caused excessive spherical aberration, especially with the single lenses then tried. "Thus at last I obtained a perfect theory for making object glasses, to the apertures of which I could scarcely conceive any limits." Dollond brought a great stimulus to the search for improved optical glasses when he put a double concave flint-glass lens between two convex crown glasses of lower curvature; his son then proceeded to manufacture such lenses. It may be noted that Chester Moore Hall had made similar lenses 33 years previously, but he kept his method secret, or at least did not acquaint opticians with their possibilities. Peter Dollond's shop was at first situated in the Strand, but later moved to St. Paul's Churchyard where large workshops produced optical instruments of many types.

A successor to Hall and Dollond is worthy of mention before passing to his contemporary, Michael Faraday. This was William Vernon Harcourt, a clergyman who became the founder of the British Association for the Advancement of Science. Inspired by his tutor, Dr. John Kidd of Christ Church, Oxford, Vernon Harcourt took a life-long interest in chemistry He fitted up a laboratory and helped by Davy, Wollaston and Stokes he became proficient enough in science to produce glasses during his 40 years of experimenting, making them on a small scale for achromatic combinations and including about 30 different oxides in his melts, including those of boron, phosphorus and titanium.

The work of Faraday

Early in the last century Faraday, along with Sir John Herschel, Dollond and others, became a member of a committee set up to study the manufacture of optical glass. His results, published as the subject of the Bakerian Lecture for 1830, form yet another phase in the early development of optical glass. It is true that Faraday himself was rather pessimistic as to their value, just as he deplored the fact that none of the members of the committee was a practical glass-maker. But Kater and Pond examined telescopes made with Faraday's glass and pronounced them good and very achromatic. Faraday worked at first at the Falcon Glass Works; later a furnace was erected in the yard of the Royal Institution where his faithful servant, Sergeant Anderson, assisted in the experiments and prepared "frits" or compositions ready for fusion. Faraday was much concerned because Dollond had not for several years been able to obtain a disc of flint glass of four and a half inches diameter fit for constructing a telescope. Whereas on the Continent the Swiss mechanic Guinand (who invented the method of stirring optical glass in the furnace) had begun in a small way in 1784 to prepare some glass, and Fraunhofer was yet another European worker to set up a glasshouse for the preparation of such special glasses, in this country it was left to Faraday alone to fill the gap between the Dollonds with their skill in grinding lenses and their great interest in optical glass, and the coming of George Bontemps, that versatile Frenchman who did so much to help forward the British industry. With characteristic patience Faraday laboured in his glasshouse, carefully purifying the lead oxide he prepared from the nitrate, his boric acid (tested for traces of iron and re-crystallised to purify if further), and his silica sand which came from the Norfolk coast. He used a platinum tray for melting the frit, making it from a selected platinum ingot and patching any small holes in it with a platinum-gold solder. (Faraday, like Wollaston, must always be included in any history of the development of platinum-working). A platinum stirrer, repeatedly cleaned with nitric acid, completed the apparatus used in this investigation, the account of which came to occupy considerable space in the *Transactions of the Royal Society*. He charged his tray with "silicated-borate of lead" prepared by Anderson, a constituent so essential to modern optical glasses; and he prepared and examined no less than 215 samples of glasses.

Smethwick and George Bontemps

Practical developments during the last century centred around the glass works at Spon Lane, Smethwick, where Messrs. Chance Brothers became, and remained until recent years, the sole makers of optical glass in the United Kingdom. The methods of Guinand (who, it is believed, first made spectacles for his own use, and constructed telescope with his lenses mounted in cardboard tubes) were adopted not only at Munich, after the optician Utzschneider had persuaded Guinand to work with Fraunhofer, but also came to this country, via Bontemps. Guinand's process are still in use to-day—its basic principles consisted of continually stirring the melt; of allowing it to cool slowly in the glass pot, breaking up the latter, and breaking the solidified mass into pieces from which the best are selected for making discs or blanks for the lens-maker. Faraday's reference to Guinand and Fraunhofer in his Bakerian Lecture—"it is certain that the public are not in possession of any instruction relative to the method of making a homogeneous mass fit for optical purposes, beyond what was possessed before their time"—must be read in the light of his surmise that "the knowledge they acquired was altogether practical and personal, a matter of minute experience". Meanwhile France was benefiting from the work of Guinand's son Henri, who was working with Bontemps, for a number of successful discs came in 1828 from the works at Choisy-le-Roi. In May, 1837, Lucas Chance enabled the manufacture of optical glass to be started at Smethwick by arranging that Bontemps should be paid for his "instruction" by the same amount that he himself had paid Guinand *fils*, viz. 3000 francs. A year later Chance took out an English patent (No. 7596) for Guinand's process and erected a furnace—a small one, since demands for the Smethwick patent plate glass and other forms of glass took precedence, having "ten times the importance" of optical glass.

It was not until 1848 that Bontemps arrived and the new plant began to take shape (up to that point ordinary crown had been made at Smethwick for the use of Dollond). Bontemps began by preparing "hard crown" and "dense flint" for telescopes, the former containing potash instead of soda, while the dense flint was produced by using equal amounts of red lead and sand in the mix. Bontemps also made "soft crown" and "light flint" for camera lenses, and later began to increase the red lead content of his flints. Four years later he was able to show a new dense flint glass to German opticians (at this time the Zeiss-Abbe-Schott combination was not yet born). He was also able to make an "extra dense flint", with the proportions of 128 parts red lead to 100 parts of sand, and this was in demand in Berlin for microscopes. After 1867 he made a "double extra dense flint" with a 9:5 proportion of the last-mentioned constituents and a density of 4·45. Meanwhile Bontemps had not only permitted London opticians to replace their flints of Swiss manufacture by an equal or even better article from their own country, but he travelled on the continent representing Messrs. Chance, met the chief opticians in Germany and Austria, and obtained appreciable orders from Voigtlander and Ploessel.

By the year 1851 British optical glass had become well established. The Great Exhibition of that year saw discs of Messrs. Chance on view, including a specimen 20 inches in diameter, a nine-inch achromatic lens constructed by Simms, discs and plates "for the construction of object glasses for Daguerrotype and Talbotype apparatus and cameras", and a *chef d'œuvre* in a 29-inch disc of dense flint, 2¼ inches in thickness and with no striae or bubbles of import. (Very small bubbles were not too significant —"optical glass is made to look through, not to look at", as Fraunhofer remarked on one occasion). This latter disc, polished by Ross and awarded a prize, was shown at the Paris Exhibition in 1855 along with one similar but of crown glass, which Foucault pronounced to be the most perfect and pure piece of glass he had ever seen. A pair of 20-inch discs for photographic purposes and a 16-inch pair for a telescope were also shown. Yet the British Government of those days lacked interest in such things

and could not be persuaded to buy the pair "to construct the greatest achromatic telescope that has ever been contemplated by the most sanguine astronomer", as Sir David Brewster put it in his Report. But the French government bought these British specimens despite the increasing competition of French optical glass made by Feil, grandson of Henri Guinand. Nevertheless, the interest shown in their products roused the Chance organisation to order that twelve large and six smaller pots for optical glass should always be kept in stock for meeting any requirements. Bontemps, after returning to France and leaving his cousin to look after the manufacture of optical glass at Smethwick, drew one quarter of the profits from the production; in return he undertook to assist no other manufacturer.

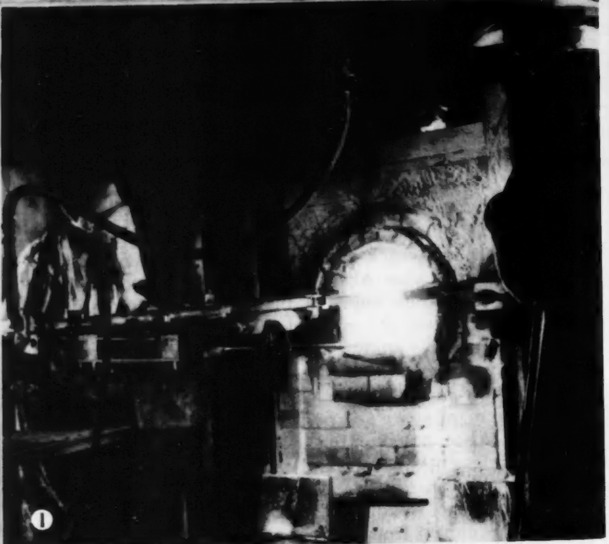
The next twenty or thirty years brought further examples of the success attained by British optical glass. A pair of 25-inch discs were converted by Cooke of York into an object glass that was eventually used at Cambridge. A 20-inch equatorial telescope incorporating two discs rejected by the French government because of a flaw in them was constructed by Buckingham, who eliminated this flaw in shaping the lenses. Another disc went to Alvan Clark of Boston, Mass., to become an object glass for the telescope of the University of Chicago—"The 18-inch is the best definer we have ever seen. The discovery of the companion of Sirius has established the character of the glass and won for us the Lalande Prize" was the comment from the United States. In later years yet other glasses went to the Naval Observatory at Washington and to Chicago. It must be noted, however, that the Feil concern of Paris, with their larger furnaces and pots, provided severe competition—there were, for example, the 28·3 inch flint disc they provided for the achromatic system in the Observatory of Paris, and discs larger than 36 inches for Alvan Clark of Boston. (In any event, later years brought the advent of reflecting specula and reduced the call for such large objectives). Yet despite the high cost and the difficulties of producing such large discs, where a slight accident in the making cancelled months of work spent on moulding, annealing, and so on, other discs were supplied to Greenwich, to Teramo, to Sir Howard Grubb's works and elsewhere, before the war of 1914-1919 brought, as the present one has done, a great repercussion in the world of optical glass.

Zeiss of Jena

To appreciate the position of British optical glass before and during the early years of two wars, it is necessary to review the growth of the Zeiss concern which almost established a world monopoly in optical equipment so essential to modern warfare. In 1846 Carl Zeiss established at Jena a workshop for the manufacture of optical instruments. He was joined in 1866 by Professor Abbe and in 1881 by Dr. Otto Schott. It had been early realised in Germany that the range of optical glasses was far too limited; yet, as in England, glasshouses regarded optical glass production as a somewhat subsidiary activity. The eminent Fraunhofer was one of the first to urge expansion. Abbe was equally concerned in his succinct maxim: *For years we combined with sober optics, a species of dream optics, in which combinations of hypothetical glass, existing only in our imagination, were employed.* Up to then glassmakers had listed their products according to their densities, "just as if they were intended for ship's ballast" as Abbe sardonically put it. Abbe was determined to get rid if possible of residual or secondary spectra which constituted the drawback to achromatic lens systems of those days; it was after Abbe had discussed the requirements for greater differences in the ratios of refractive indices and dispersive powers of glasses used that Schott began his exhaustive study of the effect on optical properties of various additional constituents included in glasses. Schott made lithium glasses, for example, but they had too many striae and possessed hardly the properties which Abbe sought. But Schott persevered and, using the elements boron and phosphorus to form borate and phosphate glasses, he set to work to prepare a number of laboratory specimens for Abbe to examine; he moved from Witten to Jena in connection with this work.

In 1884 the Jena factory was built in conjunction with the two Zeiss brothers, a factory designed particularly for optical glass production with little prospect of profit. Two years later there were listed 44 compositions (including 19 entirely new ones) in the Zeiss catalogue, while Schott had made over 1000 experimental kinds in his laboratory. Since Vernon Harcourt had prepared samples of glasses containing boron and barium, and Maes of Clichy had made some containing boron, zinc and barium, Schott did not introduce such elements. What he and Abbe did was to study systematically the relation between optical properties and compositions. Boric acid and barium oxide solved their problems, and Jena began to flourish with the Prussian Ministry of Education granting a first subsidy of £3,000. Later there was established the Zeiss Foundation, a quasi-state controlled and state-administered concern which was supported partly by the German Government and which became the largest manufacturer not only of optical instruments but in particular of military optical equipment (one may note that there was a strong military element in the directorate). Subsidiaries of the Zeiss Stiftung were established in other German cities and other countries, so that by 1939 Zeiss products had become world-wide in distribution.

In 1886 the growth of this organisation began to make its effects felt at Smethwick. Two years later Voigtlander, as an old customer of the British firm, expressed regret at having to adopt the new barium flints of Jena, especially because pressure of the Prussian Government restricted his use even of the British crown glass. Research was begun in this country, yet because of some impurity in the barium minerals barium flints did not prove successful here until early in the nineteen-hundreds. Indeed, in face of the subsidised Jena concern it was proposed at one period to abandon optical glass production in Britain. Fortunately for the critical years of 1914 onwards this was not done, although Zeiss was dominating the world's markets. For example, France, "the country of Foucault was a payer of tribute to Zeiss"; in the United States the firm of Bausch and Lomb had come under the control of Zeiss, and had to purchase all their glass from Zeiss, a handicap which fell heavily on America particularly when the two World Wars started.



THE MANUFACTURE OF OPTICAL GLASS

1. Stirring a pot of molten optical glass. 2. Taking a sample from the pot. 3. "Opening" a pot of optical glass. 4. Cracking the glass into lumps of suitable shape and size. 5. Moulding lens glass. (*Photographs by courtesy of Chancz Brothers, Ltd.*).

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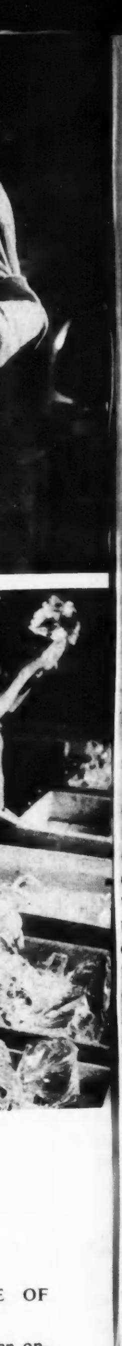

The two wars

By August, 1914, there had been installed at Spon Lane a Belgian smoothing machine for grinding and polishing discs, an electric annealing plant, and a mechanical stirring machine for the molten glass. With the supplies of German optical equipment cut off, "it came as agreeable news to the War Office that optical glass was made in England also". New gas-fired furnaces had been installed and new British barium and zinc crown glasses and a light barium flint had already appeared. Potash supplies, which had come from Stassfurt (later British potash became available from the Dead Sea), were difficult to obtain, and the pure carbonate had to be manufactured at the high price of £150 a ton. Another British deficiency, this time inexcusable in view of our extensive deposits, was in pure barium compounds suitable for optical glass, so the Chance organisation had to make their own. By use of electric machinery for setting and removing pots from the furnaces it was found that three furnaces could be made to produce as much as five had done previously. After Mr. Lloyd George took control at the Ministry of Munitions, Messrs. Chance were permitted to extend their activities to produce 14,200 lbs. optical glass per month, to fit up a research laboratory, and to manufacture barium light, medium and dense and borosilicate glasses.

So great was the demand for optical glass following striking advances that occurred in aerial photography from 1916 onwards that the British government approached other glass-making firms with a view to increase yet further necessary supplies. For example, Messrs. Wood Brothers of Barnsley began at their Derby works to manufacture it, experimental work being undertaken by Dr. Peddle and various batches being suggested by Sir Herbert Jackson for use by a concern with no previous experience in this direction. When the Schott concern developed glasses from arbitrary formulae, they gave refractive indices to opticians who worked out lens combinations from them; in case of British firms in war-time the reverse system operated. The last war brought increased demands for barium and borosilicate glasses for range-finders and binoculars, and for new barium glasses with the great advances in lens design. Barium additions to crown glass raise the refractive index without a great increase in dispersion and reduction in value of "reciprocal dispersive power" which lead oxide causes. By replacement of part of the silica by boron oxide the refractive index could be raised to 1·6, for example, without letting the second of the above values go beyond 59. With the new glasses the solution of alumina from the pot wall proved troublesome at first, while the volatility of boron oxide was also a problem. The outstanding success following the stimulus of war were lenses of aperture F/2, with refractive index 1·614 and reciprocal dispersive power of 59·8, these being the values given by Dr. W. M. Hampton of Smethwick. As he also has pointed out, modern cinematograph lenses became possible because of these glasses. Guinand's simple stirrer still held its place, while the purification of sand brought iron content down to 55 parts per million.

The high standard arrived at during the years 1914-19 and between the two wars has been raised yet further as a result of increased demands in the present war between mechanised forces, with planes and battleships all requiring intricate optical equipment such as range-finders, gun-sights, binoculars, periscopes, aerial cameras and so on. In 1925 the Director of Scientific Research to the Admiralty pointed out that high as were the requirements of the British Navy, British optical glass had been specified throughout and had met all requirements for optical stores of the Admiralty. To-day, there is a bulk production of the various normal types of optical glasses and in addition special small-scale melts, the latter being far more expensive yet essential for particular purposes. For the normal types the pots are brought up to 800°C., transferred to a large furnace, and over a period of 8 hours are taken to 1400°C. The mixture or "frit" is added, and the pot is topped up when the shrinkage of the molten mass occurs due to evolution of gases and vapours. After periods of up to 30 hours the mass becomes fairly free from bubbles, so that the electric stirring machine is connected while the temperature is allowed to fall to 1000°C. Next the pot is removed; it is allowed to cool very slowly throughout a week, and is then broken up with hammers and the contents of ice-like glass of up to 1½ tons allowed to drop on the floor. After breaking into lumps at inspection tables, where they are sorted for flaws and striae, the graded lumps free from imperfect portions pass to a tunnel kiln to soften the glass ready for pressing into discs. Shaped pieces, after treatment in a gas-fired muffle furnace, are cooled very slowly, opposite edges are polished for examination of the shapes or blanks, and these are now annealed to avoid internal strain.

Recently in *Nature* (1944, Vol. 154, p. 283) Dr. Hampton and his co-workers of Smethwick review, as far as secrecy regulations permit, the new types of optical glass made in smaller batches by electric heating in platinum pots—thus reverting to Faraday's method of avoiding impurities from the pot walls. The new glasses include a network of silica and boric oxides with the inclusion of zinc, barium and "other oxides". A high degree of homogeneity and higher transmissions in the near ultra-violet (3650 Å) are ensured in these special barium crowns and barium flints, British optical glass makers thus scoring another triumph and throwing forth a stimulating challenge to lens-makers to score like successes in their designs.

Technical Developm[ent]s of A

When one looks back over the long age that separates Septemb[er] ... from Ma
war in the possession of two great technical advantages. First, ... the aggress
into action. The Germans sprang the technical surprises and ... rested to
the sting of the surprise. Secondly, because Germany had been ... the Nazis
no 1914-1918 ideas in the Wehrmacht, there was no obsolete eq... tored away
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Historians will probably find that it was the worst equipped ar... e to the e
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Secrecy still surrounds a high proportion of the technical ach... s of the wa
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believe that readers will find useful this short pictorial survey ... of the mos
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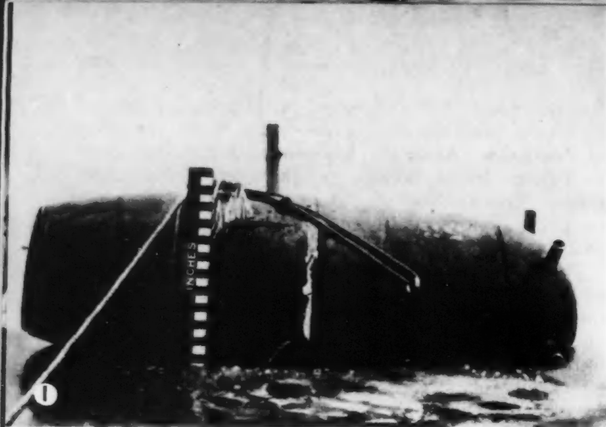

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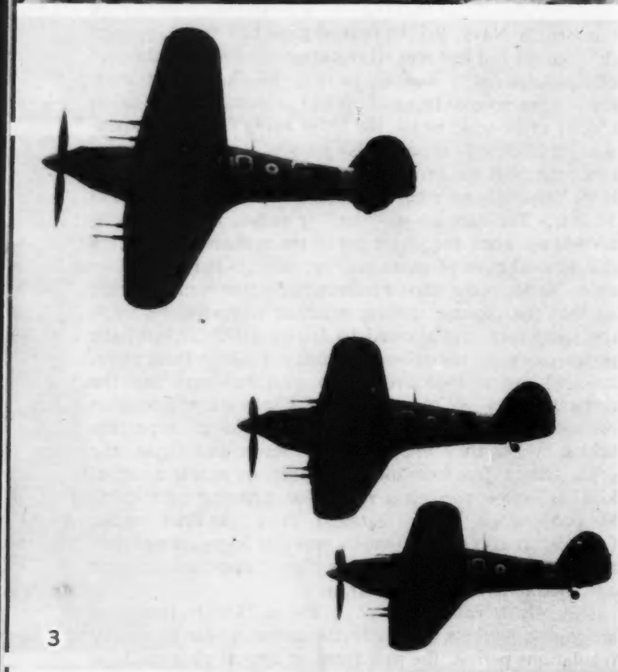

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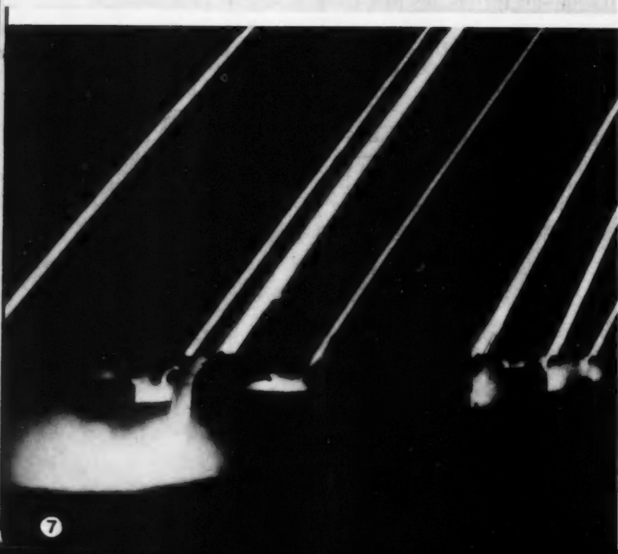

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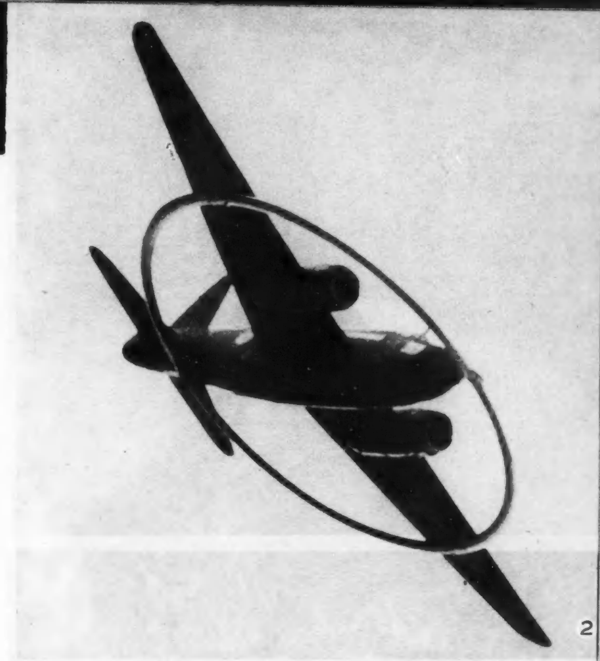

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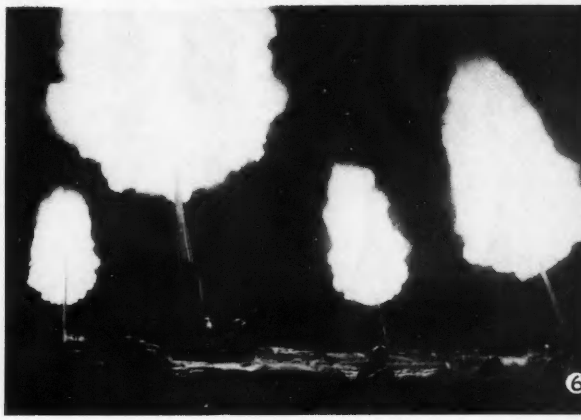

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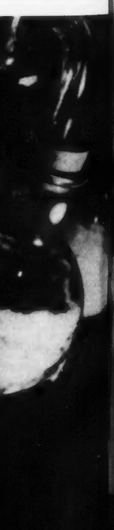

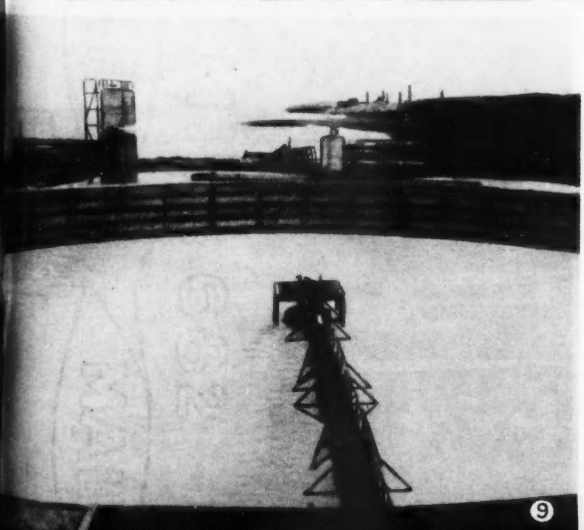

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1. At the beginning of the war most of the surprises came from the Germans. The magnetic mine was the first spectacular "secret weapon", and was launched against shipping in November 1939. In a matter of hours experts of the research establishment, H.M.S. *Vernon*, succeeded in unravelling its mechanism. Degaussing equipment was introduced to counter it. **2.** The Wellington, maid of all work at the beginning of the war, was fitted with a device for exploding magnetic mines and used by Coastal Command for this hazardous job. **3.** The Battle of Britain was won with Hurricanes and Spitfires. This is a Mark II Hurricane, with 4 cannon guns, brought into use some time later. **4.** The type of Spitfire used at the beginning of the war. **5.** Later the number of propeller blades on the Spitfire was brought up to three, and then to four. **6.** Fire control of A.A. guns has improved rapidly during the war, though many of the details of the instruments used to direct it cannot be disclosed yet. **7.** Defence by 3.7 and 4.5 guns and Bofors guns was later supplemented by rocket guns, here seen in action. **8.** Incongruous, but intentionally so, is this picture of penicillin powder produced by vacuum drying (a technique also used with blood plasma). A critical stage in the development of penicillin as a therapeutic agent had been reached by the summer of 1939; the first pilot plant for its preparation was working. **9.** The supply of many raw materials was early threatened. Here is the settling tank of a magnesium-from-seawater plant erected in Britain.

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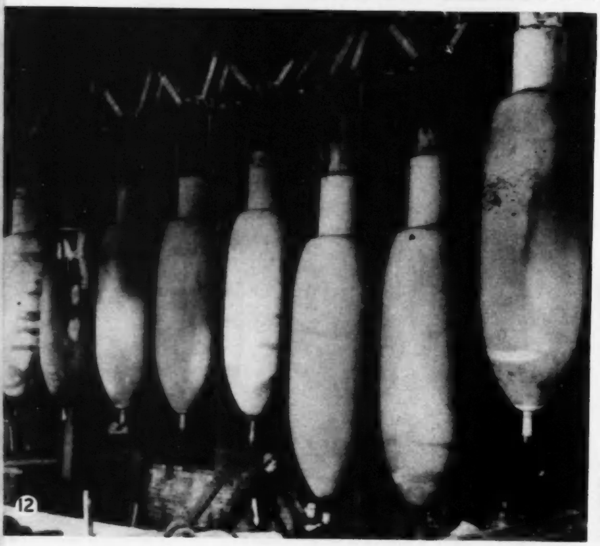

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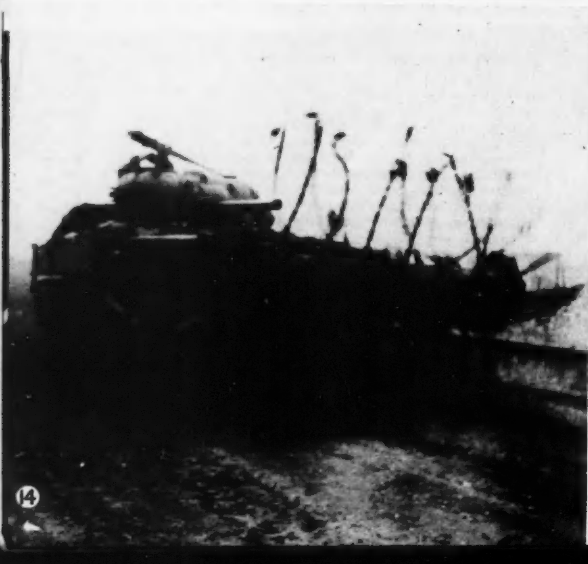

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10. Rockets have been used on land and sea, and in the air. Here is the fire of a Beaufighter directed against a German escort vessel. **11**. Another use for rockets, to assist the flight of a Barracuda from an aircraft carrier. **12**. Bombs. 22,000 pounders hanging alongside 12,000 pounders. **13**. The Challenger, the latest British tank of which a photograph is available. **14**. The anti-tank mine flail. **15**. The first British jet-propelled aircraft. **16**. One of the planes upon which strategic bombing depended. The Lancaster. **17**. Complementary to night bombing by the R.A.F. was the day bombing of the U.S. Army Air Force using Flying Fortresses (above) and Liberators. **18**. Along with the development of air power came the deployment of troops and the carriage of supplies by parachutes and gliders. The picture shows Horsa gliders (each capable of holding 28 soldiers) being towed by Whitley bombers. **19**. Again medicine cuts in incongruously. Here is a dried plasma store of the Army Blood Transfusion Service. **20**. Two remarkable insecticides have been developed during the war—DDT and 666. The former has been used to control the typhus carrier, the louse. Sprayed from planes it has proved effective against mosquitoes.

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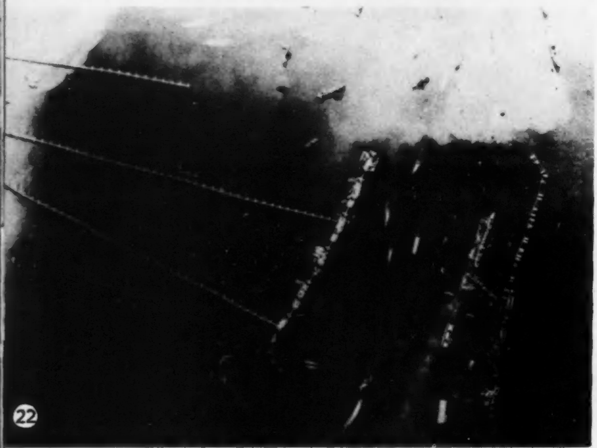

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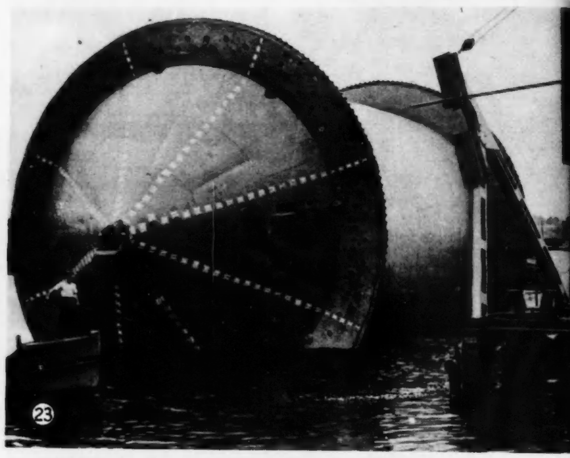

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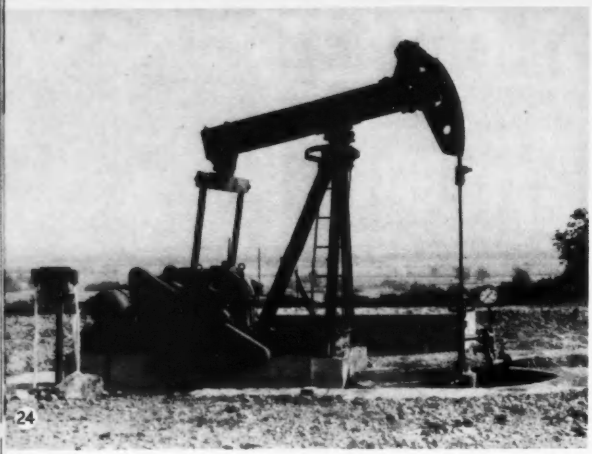

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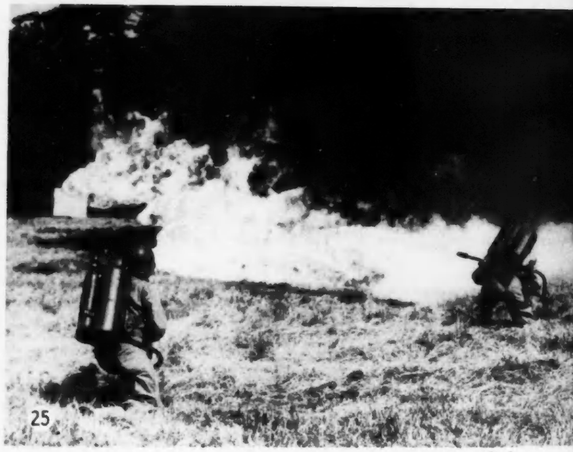

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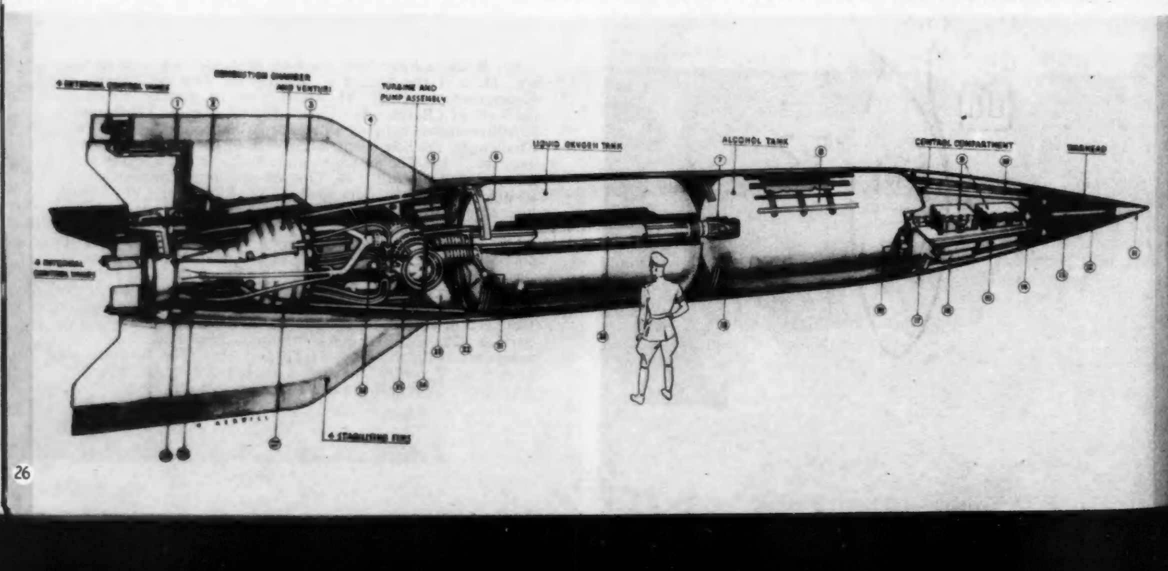

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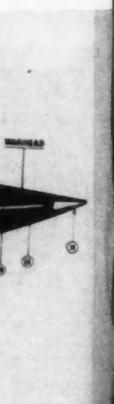

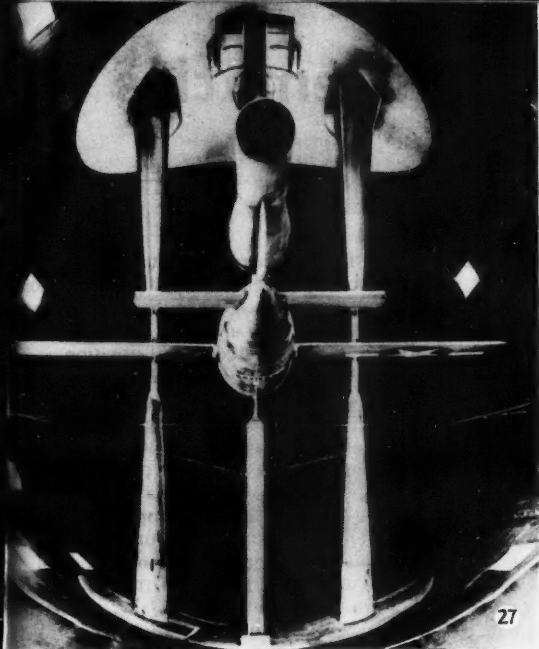

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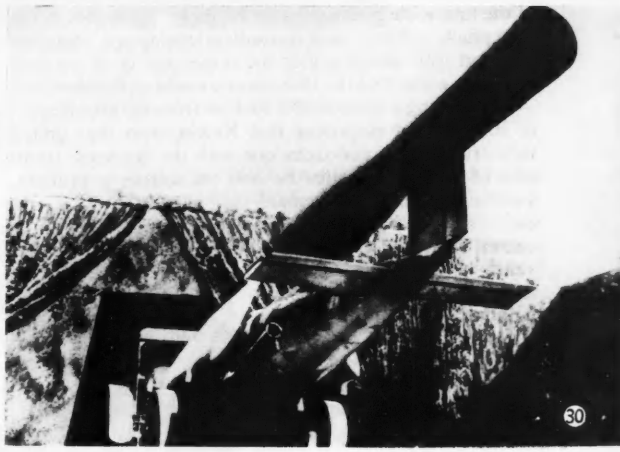

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21. One of the most considerable engineering achievements of the war was the building of two prefabricated harbours, each as big as Gibraltar. This is Mulberry, in position at Arromaches. In all 600,000 men were landed on Mulberry. **22**. An aerial view of Mulberry. **23**. Another great feat was Operation Pluto—the initials stand for "Pipe Line Under The Ocean". **24**. Of note is the war-time development of Britain's limited oil resources. This is a view of an oilfield in the Midlands with an annual output of some 100,000 tons. **25**. Chemical warfare departments have concentrated on incendiarism, rather than poison gas. Many new types of flame thrower have been devised. **26**. A sectional drawing of V2, the German rocket projectile. **27**. The Americans quickly produced a robot bomb based on the German design. **28**. Counter measures to heavy bombardment from the air have come into play. This is a gallery of a British underground aircraft factory. **29**. The Germans developed the construction of concrete bomb-proof buildings. Here are bomb-proof submarine pens at Trondheim. The Allies had devised a "power bomb", using rocket gear to give greater penetrating power. **30**. By D Day 1944 the Germans had developed new weapons peculiarly suited to a warfare of attrition. The flying bomb, V1. **31**. One of our surprises was radiolocation. No photographs of equipment have been released yet, so we are printing a photograph of Sir Robert Watson-Watt, leader of the team whose work gave us a system of radio-detecting that was worth many squadrons of fighters during the Battle of Britain.

Machinery in Mathematics

AN HISTORICAL SURVEY OF CALCULATING MACHINES

S. LILLEY, Ph.D.

IN all the types of machines so far mentioned,* England never made up for the initial disadvantage that resulted from the separation of mathematics from industrial science in the early 19th century, but in the invention and construction of the wider class of machines, now to be considered, England has played an important part, though in recent years the U.S.A. has taken the lead, perhaps again because mathematics and industry are more closely linked in that country than in this.

While the ordinary calculating machine was being perfected in France and later in Germany and the U.S.A., the division between industry and established science in England was being healed. From about 1850 onwards, science of the new type, concerned with thermodynamics, electricity and the sort of chemistry that industry can use, was forcing its way into the universities and the Royal Society. The biggest part in bringing it there was played by Kelvin, whose activities ranged from the very academic calculation of the future life of the universe by thermodynamics to the very practical business of transatlantic telegraph engineering, and who demonstrated the respectability of the new science in a way that the 19th century could well understand —by amassing a considerable fortune from the exploitation of it. It is not surprising that Kelvin, who thus united industrial science and technique with the academic tradition of mathematics (for he was, of course, a brilliant, Cambridge-trained mathematician) should have been the central figure in the new advance of mechanical methods in mathematics. It was a revolutionary advance, too, for it took us beyond mere arithmetical machines, and into the realm of machines for solving differential equations, harmonic analyses, integral equations and so on.

The uniting of mechanical techniques with mathematics was one of the main causes of the rise of the new machines. Another lay in the greatly increased complexity of the mathematical problems thrown up by the new science and the advancing industry—problems like those of telegraphy, of stresses in intricate frameworks and so on, discussed below. But another important cause is not quite so obvious.

FIG. 16.—Dr. Vannevar Bush. During the war he has been director of the U.S. Office of Scientific Research and Development.

The actual use of mathematics to solve problems about complicated machinery, or analogous problems in the electrical sphere, provided a new way of thinking for mathematicians. If a mathematical equation adequately represented the motion of the machine, then the motion of the machine equally represented the mathematical equation *and could therefore be used as a means of solving the equation.* That was a new mathematical situation.

The men of the 17th century had plenty of machines, but they did not apply much mathematics to them—the machinery was not complicated enough to require it. They had plenty of mathematics, but it was not primarily applied to machines. It was applied to things like the motion of the moon or the motion of a projectile under gravity. And you cannot reverse that application and use the observed notion of the moon or the projectile to solve mathematical equations, for you cannot control the conditions as you wish. So that it was virtually impossible for the idea of using a machine to solve, say, a differential equation to arise before the 19th century.

Apparently, the last time that mathematics was applied in some new sphere of such a nature that the process could be reversed to give a new mathematical method was very near the beginning of mathematical history. One of the earliest problems of mathematics clearly was of the following type: "We have 17 sheep, a number which we have determined by counting, in one meadow, and 35 sheep, also determined by counting, in another meadow; if we count the whole lot, what answer shall we get". The process of adding 17 to 35 is a short-cut to save the trouble of counting the whole lot. But this application of elementary mathematics is capable of reversal. If addition gives the answer to a counting process then a counting process can be used to give the result of addition. And, of course, it was—for early addition consisted in the use of some sort of abacus, which is essentially a counting process.

Nothing analogous seems to have happened in mathematics until the 19th century. From this point of view, the calculating machines of the 17th century were nothin *fundamentally* new; they were merely mechanisations of the abacus—for the ordinary calculating machine is merely an abacus in which the pushing forward of one tooth of a gear-wheel replaces the familiar movement of a bead or a counter. By the 17th century men's knowledge of machines was sufficient to permit them to mechanise the familiar abacus. But, since they had not to any great

* Continued from page 156 of the May issue.

By courtesy of "The Mathematical Gazette" and Metropolitan-Vickers

FIG. 17.—General view of a differential analyser. The principle elements of this machine are shown in Figs. 18 and 19. The integrators and torque amplifiers are contained in the cases on the left, the rest of the machine consisting of interconnecting gearing, recording mechanism and apparatus for feeding in empirical functions from graphs.

extent applied mathematics to machinery, they could not use machinery to provide *fundamentally new* mathematical methods. Even to-day the vast majority of purely arithmetical machines remain merely mechanical versions of the abacus, though a few modern examples have gone a step further by incorporating an actual multiplication table in their mechanism. But meanwhile these *arithmetical* machines have been submerged in the far wider class of *mathematical* machines, whose history dates almost entirely from the latter part of the last century.

The men of the 19th century, unlike those of the 17th, were familiar with the application of mathematics to complicated mechanical problems of many types and so they could reverse the connection and use machines to produce fundamentally new mathematical methods. They did; and the mechanical methods which they introduced were in a broad sense the first advances in the basic processes of mathematics since the abacus, all that came between being merely a memorising systematising and short-cutting of the abacus process, whether it be by the algorithms, by tables of logarithms, or by reducing differential equations to difference equations. Formerly the object of mathematical science was to reduce each problem to one of arithmetic, essentially one of the abacus; now the object is to reduce it to a form in which some machine or other can complete the work, often without any intervention of arithmetic except in the notation used for recording the results. And this fundamental change was largely due to the fact that men were now so familiar with the application of mathematics to describe and predict the motion of machines, that they were at last able to appreciate the reverse connection, the use of an appropriate machine to represent and therefore solve a mathematical problem.

As the requirements of technology and science have grown, the number of these machines has also grown, so rapidly that we can do no more than mention a few of them and the problems with which they were connected.

Fundamental to a very large class of mathematical problems is the differential equation. A large number of instruments called "integraphs" were produced to solve special differential equations. But these are of little importance beside Kelvin's proposal for the mechanical integration of any ordinary differential equation. The principle of the thing is simple. The essential element, the integrator, is a continously variable gear, which was already familiar in many integraphs and planimeters. The big step forward is to realise that by suitable mechanical connections between such integrators a machine can be produced to solve any differential equation. Kelvin pointed this out in regard to linear equations in 1876.

But he failed to overcome the difficulty that the friction drive from the integrator is not sufficiently powerful to drive the further mechanical connections which are required. And this difficulty was not overcome till 1931, when Bush of the U.S.A. solved the problem by means of the "torque amplifier". The principle of the torque amplifier is again extremely simple; it is essentially the same as the capstan of a ship. The capstan is kept rotating, a rope is wound round it, and it is found that a small pull on one end of the rope produces a much stronger pull on the other end. Kelvin, in fact, might have produced a complete differential analyser (as Bush's machine is called)

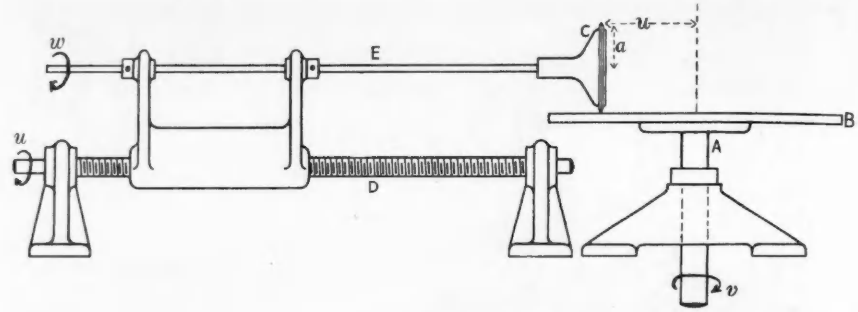


FIG. 18. (*above*)—The *integrator*, the basic unit of the differential analyser. In essence this is merely a friction-driven variable gear, the gear-ratio depending on the distance of the *integrating wheel* C from the centre of the *integrating disc* B. The independent variable v is represented by the revolutions of the disc B on the shaft A. The variable u, which is to be integrated with respect to v, is fed to the shaft D and, through the screw mechanism, controls the distance, u, of the wheel C from the centre of B. If u remains constant, then when v rotates through v revolutions, C will rotate through uv revolutions (taking the radius of C as unity). But if u is made to vary as a function of v, then C will make w revolutions, where w is given by $w = \int u dv$ or $\frac{dw}{dv} = u$. Thus the mechanism performs the operation of integration. By connecting several such units together in various ways, any differential equation can be solved. For example, if the shaft E is made to drive D, so that $u = kw$, the machine would solve the equation $\frac{dw}{dv} = kw$. The value of w for each v would be represented by the number of rotations of E. If A and E are made to drive a pencil in horizontal and vertical directions, respectively, over a sheet of paper, the pencil will draw the graph representing the solution of the equation (in this case the exponential curve).

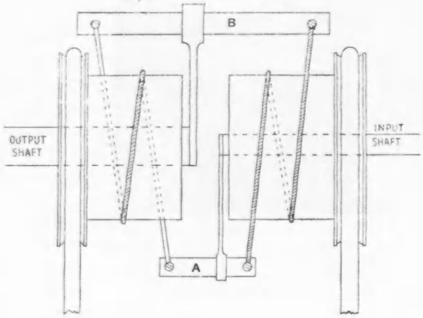


FIG. 19 (*left*)—The *torque amplifier*, used to convert the weak friction drive from the integrating wheel into a strong torque capable of driving the rest of the machine.

in 1876, if he had happened to mention his difficulty to the deck-hand of a tramp steamer, or one of the many other workmen who use the capstan principle. In that way is scientific advance retarded in a society in which scientists and deck-hands do not usually move in the same circles. And it is interesting to note that Bush, who actually solved the problem, is one of those who are particularly concerned about the social questions connected with science; his attitude in this may have some relation to his ability to synthesise mathematics with a common technique.

Wave motion problems probably rank next in importance to differential equations in late 19th century mathematics. They occur, for example, in telegraphy, which was then rapidly developing and in the ever-important problem of forecasting the tides. The latter, of course, had been important for a long time, but singularly little progress had been made with it, largely because the earlier attempts were synthetic ones, attempts to produce general formulae for tidal phenomena. Gradual accumulation of evidence showed that the problem was too complicated for this method. Thus Kelvin was led to suggest in 1876 to the British Association committee on the subject the alternative *analytic* method: to analyse the tidal curve into simple harmonic components, extrapolate these into the future and then synthesise them to produce the future tidal curve.

These problems of telegraphy and tides, and many others lent great importance to the mathematics of harmonic analysis and synthesis. And there was a great crop of machines to avoid the tedium of arithmetical solution of such problems.

Kelvin in 1876, invented a harmonic analyser involving the use of an integrator of the same type as occurs in the differential analyser, and also a so-called "tide-predictor", a machine constructed to solve the problem which its name indicates, but actually applicable to harmonic synthesis in general. Many other harmonic analysers and synthesisers followed between 1890 and 1910 and there has been a new crop of them in recent years, apparently connected with the wave motion problems of radio, the "talkies", quantum theory and with the mathematics of X-ray crystallography.

Simultaneous linear equations occur in many important connections, for example, in engineering frameworks. Kelvin was once more first to produce a machine for their solution and a number of others have since been invented, notably the electrical one of Mallock of Cambridge (1932).

A recent development, belonging to the last ten to fifteen years, is of machines to solve integral equations, a type of equation that occurs wherever the past history of a system affects its future (for example, in hysteresis and in many biological growth problems) and one that provides a very powerful tool for solving partial differential equations.

But it is useless to try to enumerate all the types of mathematical machines that have been produced or could be produced. After all, as we have said already, if a mathematical equation represents the motion of any machine, then that machine can be used, more or less conveniently

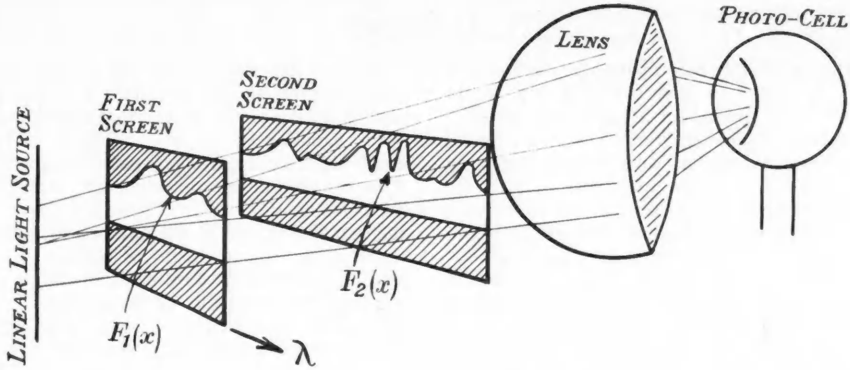


FIG. 20.—The principle of the *photo-electric integraph* or *cinema integraph*. Light is given out by a linear source. It is easily seen that the amount of light collected by the lens and passed to the photo-cell is proportional to $\int_a^b F_1(\lambda - x)\, F_2(z)\, dx$, where the parameter λ is introduced by moving the first screen horizontally. The current from the photo-cell thus represents this integral. When coupled with suitable automatic balancing and other devices, this apparatus forms a powerful tool for the solution of integral equations. If one of the screens is given a cosine function, the apparatus becomes a *harmonic analyser* (one of many types). The functions may be represented by varying the density of the screens instead of the heights of the open parts. In the cinema integraph the first screen is merely one of a whole series of alternatives, each recorded on one frame of a cinema film. These can be successively snapped into position and a whole series of related integrals evaluated very rapidly.

according to its nature, to solve the equation. That is not a useful piece of knowledge if the machine is the only thing described by that particular equation, but if, as is usually the case, the equation can be applied in other connections, then the solution by one particular machine may be useful. So we get the most weird contraptions used for quite important mathematical purposes—rubber sheets variously stretched to solve the two-dimensional Laplace equation, almost any sort of electrical circuit and so on.

One development that has *not* taken place yet is the application of *physical* (rather than mechanical) methods to the mathematics of probability. Now that we are applying probability methods wholesale to the deeper problems of physics, it seems reasonable to expect that soon we may see another reversal of the connection, the use of the deeper physical systems to solve probability problems and, who knows, perhaps even an application of physics in this way to problems of social statistics. Similarly there is the possibility that biological systems of some types (controlled ecological systems of bacteria, for example) may provide some of the mathematical methods of the future. But all this is speculation. So let us end with a word or two on the present position of mathematical machines.

There is every sign that a very thorough appreciation now exists of the power that mechanical methods can add to the mathematician's elbow. But it also seems that there is as yet no real appreciation of certain conditions that must be fulfilled if that power is to be fully used. Many of these machines cost thousands of pounds to build. Any scientist can afford a slide-rule; a few of them can afford a Brunsviga machine. But it takes a very large institution to buy a machine like the differential analyser, while the use of mathematical machines is not fully efficient till many such machines are gathered in one institution. So far such institutions as do possess collections of mathematical machines are either closed academic corporations, like the Massachusetts Institute of Technology, or commercial computing services, working to the orders of customers. The former, very naturally, tend to restrict the use of their machines to their own members; the latter apparently cannot accumulate sufficient capital to obtain the use of the more expensive and specialised machines.

It is clear that the fullest use of mathematical machines can only be made through the establishment of central organisations on a national (and perhaps even an international) scale, organisations which could be equipped with a full range of machines. In both fundamental science and technology, to say nothing of the vast statistical work of the social sciences, investigators are finding more and more that the mathematical problems they meet require mechanical aids far beyond the resources of the individual laboratory. Such problems they could send to a central institute for solution. The proposal to set up a Mathematics Division of the National Physical Laboratory, which would include this among its functions, is therefore to be welcomed. It is to be hoped that it will receive the very generous financial allocations necessary to make a success of such a venture. It is also to be hoped that its services will not, as at present seems to be intended, be confined to Government departments and industry—fundamental research, which is ultimately of even greater importance, has equal need of its aid, while provision must be made in this or some other organisation for the biological and social sciences.

Can "Scientific Management" become Scientific?

S. J. MOORE

MUCH attention has recently been focused on the question of the greater utilisation of science in industry. From many directions come appeals for a wider application of the scientific method, increased research facilities, better co-ordination between research workers and industrial technicians, new processes, new materials—in fact, for anything and everything that science can do to increase productivity. And given the right opportunities, there is no doubt that the scientist will be able to do most of what is asked, and a lot more besides. In this bright and cheerful picture, however, there is one shadow that seems to have been largely overlooked. No matter how technically advanced industry may become through the efforts of physicists, chemists and engineers, production processes, at some stage or other, will always include the human element and it is here that the chain of mechanical perfection will lose its continuity. Can science deal also with this problem and improve the efficiency of the worker at the same time as the machine?

In many respects *homo sapiens* may be regarded as a mechanical contrivance—physiological theories are mostly based on such an assumption—but until our knowledge of mental processes is greatly extended beyond its present boundaries, we are not justified in so viewing the human worker. Yet over the past fifty years a complex system of industrial management has grown up, based entirely on this false premise. Not that the mechanistic principle is actually postulated—that would be too bland an admission—but its tacit assumption is very obvious from the methods employed. Unfortunately, the system has acquired the title of *Scientific Management*, and before proceeding to any consideration of the question asked above it will be necessary to review the results obtained by the "scientists" who practise this enlightened form of management.

Taylor and Gilbreth

The story begins in the latter quarter of the last century when a young engineer, Frederick Winslow Taylor, an apprenticed mechanic, was promoted to the position of chargehand in the machine shop of an American factory. His new position gave him the opportunity to try to overcome the practice by the men of deliberately underworking, that is, of making the job "hang out". Needless to say, his efforts met with little success and a lot of abuse; but they did gain for him the confidence of the management to the extent that, when he suggested making experiments to determine just how much work an individual was capable of doing, he was granted the necessary facilities. The first investigations were designed to measure the rate at which physically fit men could perform work of a purely manual nature. It was found that, for a given rate of expenditure of energy, a man could only remain under load for a certain fraction of the day. This discovery led to recognising the necessity for frequent rest periods to allow tired muscles to recover, a fact interpreted by Taylor in terms which largely anticipated the modern description of muscular fatigue.

His next step was to apply the new knowledge to some practical problem and he started by studying the crudest and most simple manual operation to be found in his works—the handling of pig iron. A gang of labourers was employed in loading iron pigs (weighing about 92 lb. apiece) from the ground into railway trucks drawn up alongside, each man handling on an average $12\frac{1}{2}$ tons per day. From the figures obtained in the tests Taylor calculated that a man's daily average should be between 47 and 48 tons! Careful observations were made of the manner in which the men performed this operation and, also, of the men themselves, their habits, physique, character, and so on. Next Taylor chose one man who was physically robust, conscientious and of good character but of low intelligence—"ox-like" is Taylor's description. A bargain was made whereby he would receive 60% increase in wages provided he did exactly as instructed during the whole of his working day. By this means he was made to work at a constant rate for short spells followed by roughly equal periods of rest. When the man finished working at 5.30 p.m. on the first day of the experiment he had loaded $47\frac{1}{2}$ tons of iron *without overtaxing himself*.

This feat was later to become the regular performance for the whole gang, or rather for those who proved physically capable of keeping the pace. The 60% higher wage was paid to all who maintained this output.

Taylor followed this initial success by reorganising all the outside labouring jobs throughout the works. In so doing, he frequently found it necessary to design special tools for specific tasks. For example, in shovelling operations it was found that the highest efficiency could only be achieved by keeping the load on the shovel constant, and this meant providing shovels whose size was inversely proportional to the density of the material to be handled. Over a period of some three years the number of labourers working in the yard was reduced by 75% while the output of the remainder was increased 370%. For this they received an average wage increase of 65%. The saving to the firm was at the rate of 75,000 dollars per annum. Against this last figure the benefits for the worker that the new system created seem rather insignificant but Taylor claimed that wage increases larger than about 65% were detrimental in effect. The men, he said, became irregular in work and extravagant and dissipated in their living. He also stated that all men becoming redundant in one class of work were reabsorbed elsewhere in the factory.

The doctrine of "Scientific Management", the name given to the system by Taylor, soon achieved a certain popularity among the industrialists, particularly in the country of its origin. Other workers began to extend the field of activities and develop new techniques. Notable among the new workers was F. B. Gilbreth who attempted to revolutionise the craft of bricklaying and was responsible for laying the foundations of the analytical method known as time and motion study.

The foregoing examples of Taylor's early work illustrate all the essential points of "Scientific Management" as he saw it; these are as follows:

1. Thorough knowledge by the management of the

work, the best method of procedure and the maximum output to be obtained consistent with the well-being of the worker.

2. Adequate instruction for the worker on the correct method of working.

3. Careful choice of the worker for the job.

4. Suitable incentive to the worker to keep up his output in the shape of increased wages.

Now, for any industrial organisation to deliberately employ and maintain these principles demanded a certain philosophy on the part of the executives. Taylor considered that the maxim "*prosperity for the employee, coupled with prosperity for the employer*" met the case and, for the conditions then prevailing in the United States, he was probably right. At that time America was still in the period of rapid economic expansion; markets were apparently unlimited, there would always be someone to under-sell; greater production could only mean greater profits, and if a little of the increased revenue was shared among the employees their potentialities as consumers would be enhanced and the market, directly or indirectly, would benefit again. Thus reasoned the industrial leaders, and to reason was to act. One new method after another was developed to increase the rate of production, and gradually there evolved mass-production as we know it to-day. The maximum output from each worker was at last ensured, for now the pace could be set by the speed of a moving belt.

Social repercussions

As might be expected, the new system was not well received by the workers. Although Taylor had not himself experienced labour troubles in his own factory, those who followed him were not so eager to expend time and energy in fulfilling the moral obligations to their work-people in the manner he had advised. Consequently there arose disputes as bitter as any since the days of the first trade unions—disputes with all the attendant miseries of strikes and demonstrations, riots and machinery wrecking. This led the business owners to adopt a rather critical attitude to "Scientific Management" although they were still anxious to introduce the various technical improvements that were connected with the system. Time and motion study, for example, is a good thing because it lowers production costs, but "Scientific Management" is dangerous—it promotes strikes. That was the lesson taught by events, and that is the sort of position that exists at present. Most workers of to-day have either direct or secondhand knowledge of the system in one or more of its modern guises, such as the Bedaux system. Those knowing anything about the latter will be able to appreciate the workers' distrust of an administration called by the name *scientific*. The employers, on the other hand, may be divided into three classes with respect to their relation to "Scientific Management". There are those who practise it, those who profess to know it but to have nothing to do with it, and lastly, the majority who have never heard of it. All, however, take advantage of the fact that many of the system's features have been separately incorporated in industry by a gradual assimilation. In that way, introduced one by one, processes such as time and motion study, tool standardisation, costing, and the like, do not give rise to the voilent opposition experienced when bringing them in all at once.

Such is the history of "Scientific Management" to date. It may be said to be the story of how professional business tried to use its own brand of "science" to solve the problem of the human element in industry. It has been described at length in order to show that there are grounds for believing that any future attempts at increasing the efficiency of workers will be strongly opposed. Yet the desirability of such attempts, in the workers' own interests, is manifest. The standard of living of the whole world must be raised and there is only one way of doing it; by increasing production all round. Obviously, some new approach to the problem is required. Can science, true science, that is, provide this?

While the business profession was developing its idea of the worker as a machine, the new study of psychology was interesting itself in the human as a worker. As with all young sciences, progress was slow at the start. The necessary co-operation with the business world was lacking and it was not until the World War of 1914-1918 that any real attempt was made to utilise in industry the special knowledge and experience of the psychologist. Even then, the lead had to come from the government departments rather than the industries. In Great Britain in 1915, a commission was set up, the Health of Munition Workers' Committee, having among its members a noted psychologist, Dr. H. N. Vernon, to study the serious problem of falling output in the munition factories. Despite the 90 hours or so that the workers were putting in, production for an entire factory was frequently less than normally to be expected for a 60-hour week. The committee published a series of papers culminating in a final report that appeared in 1918 and in which many practical recommendations were made, recommendations that further experience has shown to be very sound. It is most unfortunate that the lessons contained in this report were not more widely appreciated, for we have seen most, if not all, the mistakes in administration and organisation to which it drew attention repeated in the second World War.

However, this committee's efforts did make some impression for after the war a permanent body was established, the Industrial Fatigue Research Board, later to become the Industrial Health Research Board. At the same time, again in England, was founded an independent concern, the National Institute of Industrial Psychology. Elsewhere in the world similar events were taking place. The United States were already under way with a well established branch of industrial psychology to which goes credit for the first mass-test of intelligence. When U.S.A. entered the war in 1917 about two million men were examined by intelligence tests to enable the military authorities to group them for training purposes. Men of intelligence so low that the ordinary system of training would not have benefited them were rejected in the same way as the physically unfit; those with intelligences above the average were chosen for training as N.C.O.'s., and so on. The same year, 1917, saw the founding of the Australian Institute of Industrial Psychology. Other countries followed suit during the twenties and by the outbreak of the war in 1939 every nation with a production industry of any size had its body of industrial psychologists.

The result of this widespread activity has been a rapid

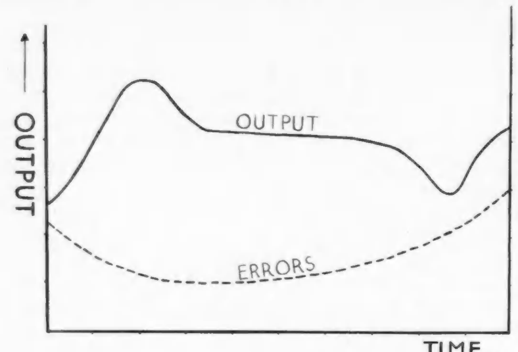


FIG. 1.—Normal output curve for work of a repetitive nature. The rate is low at the start and rises rapidly to a maximum after which a slight drop occurs and the output becomes steady. Towards the end of the day as fatigue begins to set in the curve declines to a point when the almost immediate prospect of finishing produces a final spurt. The dotted line shows the corresponding curve for the percentage error, i.e. the percentage of operations incorrectly performed. (*after* Cattell).

accumulation of empirical knowledge and the development of many techniques for detecting and measuring the various influences that affect the worker. The psychologist has three main spheres of action:

1. To determine the effects of environment.
2. To determine the occupation for which people are best suited.
3. To determine the most expedient methods of working.

Under the first heading the term environment is considered in its widest sense. Not only is it taken to include the physical surroundings but also the mental atmosphere, the incentive given by superiors in moral encouragement as well as in wages, the hours of work, the effects of sickness, and all the rest of the conditions suffered by the worker, consciously and unconsciously. Many of the problems are more physiological than psychological in character and from their investigation great strides have been made in the shape of legislation to prevent exploitation of the worker at the expense of his health. Much, however, remains to be done in this direction. In his studies of environmental effects the psychologist is usually concerned to measure the rate of output under conditions which he can vary one at a time at will. This is not because he is primarily interested in increasing output, but because the rate of production is the best index to the worker's physical and mental state so far discovered. (Output here means output of correct work; that is, the effects of errors are taken into account.) A fall in the output curve will usually tell the observer that something is not right long before the worker is aware of any alteration of his own condition.

Environmental investigations are therefore mainly field experiments in which rigid control of all factors is seldom possible. Research into problems under the second heading, on the other hand, is mostly confined to the laboratory. Vocational guidance, the study of human abilities—latent or developed—necessary for coping with the demands of various trades and professions, depends on tests that can only be made under fully controlled conditions. Very briefly, the technique consists of measuring personal characteristics, such as intelligence, manual dexterity and temperament. First, figures are obtained of a number of persons already established in the different classes of employment and correlations for the degree of success achieved and the scores attained in the tests are worked out. Statistical analysis thus reveals the combinations of characteristics required to achieve reasonable performance in the jobs under consideration. From this it is only a reversal of the process to determine the type of work for which any one person is likely to prove best suited.

The science of vocational guidance has been developed to a high degree and its potentialities are undoubtedly enormous. To have shown the way to avoiding the proverbial "square peg in a round hole" with its attendant cost in happiness and efficiency is no mean effort but, up to now, it does not seem to have inspired many of those whom it could most benefit. This we have from no less an authority than the Secretary of the Medical Research Council, Sir Edward Mellanby,* who said recently:

> There are many problems still to be solved, but I want to draw your attention to one in particular which still remains to be seriously tackled. There seems to be a good deal of inertia in this country—and even some antagonism—in respect to this problem. I refer to the work of psychologists in endeavouring to fit men and women into their jobs . . . . This is an aspect of work that is probably more important than any other in relation to industrial health. It is a big problem and will require much endeavour, not only by way of research but also by trial and demonstration, to convince political and industrial leaders that their opposition to such work is unreasonable, and harmful to progress.

In the third of his activities the industrial psychologist investigates methods of working in much the same way as the efficiency expert of the "Scientific Management" school. There is, in fact, hardly any difference between the two systems in their approach to the problem, it is in their interpretations of results and the actions which follow that we see how one differs from the other. The practice of time and motion study provides a very good example of the sort of thing in mind. Strict motion study may indicate that a particular movement is quite superfluous for a given operation; nevertheless, the movement may form an intrinsic part of the whole sequence of motions performed almost unconsciously by the operator. Any attempt to inhibit or omit the movement would break this natural rhythm and impose a strain on the worker. The psychologist, realising this, would not recommend the movement to be dropped but the industrialist would probably insist on it.

"Scientific Management", or the form of industrial administration that has hitherto gone by that name, is no longer in fashion. To most people the name conjures a picture of efficiency experts imposing tyrannical systems of mechanical slavery on masses of poorly paid men and women. Reduced to the level of automatons they work interminably at one simple operation—tightening a nut on a bolt—in the manner caricatured by Chaplin

* *Health Research in Industry*, (Report of a conference on industrial health research. Stationery Office).

in the film *Modern Times*. With this impression abroad there seems little chance for any further development along the pseudo-scientific lines so far adopted by industry. But what of a true scientific approach like that of the psychologist. This, as Sir Edward Mellanby remarked, is a "big problem". Not a problem of whys and wherefores, but a problem of how to convince both executives and workers of the possibilities open to them if they will only co-operate with the scientists in the planning of an efficient industry.

The answer to the problem would seem to depend on whether the scientist has yet awakened to his social responsibility. He has devised the means but has not advertised the ends to which they lead. To end this present position of stalemate he must realise that propaganda on behalf of his science is a first necessity. The confidence of directors and piecework operators will not be won by lectures to learned societies. He must come out and show himself and, what is more important, talk about himself in a manner intelligible to the layman. The war has given the psychologist a great opportunity. Official appointments to the Services and Governments in connection with various personnel problems have given him an introduction to a wide cross-section of the nation. Has he gained the confidence and goodwill of any sizeable fraction of the community by this opportunity? If so, will he be able to exploit the position after the war? The future of any scientific approach to the human problems of an efficiently planned industry may well prove to be hinged on the answer to this last question.

READING LIST:

For those who may be interested a few works are mentioned below that give much greater detail of description and explanation than could be attempted within the scope of the present article. On Scientific Management in its original form see: F. W. TAYLOR, *Principles of Scientific Management*, 1911; F. W. TAYLOR, *Shop Management*, 1911; F. B. GILBRETH, *Motion Study*, 1911; F. B. GILBRETH, *Primer on Scientific Management*, 1912.

On general aspects of industrial psychology see: MAY SMITH, *Introduction to Industrial Psychology*, 1943; R. B. CATTELL, *Your Mind and Mine*, 1934. On vocational guidance see: E. M. EARLE, *Methods of Choosing a Career*, 1931.

On behalf of the Production Efficiency Board (Ministry of Aircraft Production), the Stationery Office recently published a booklet entitled *An Introduction to the Theory and Application of Motion Study* by A. G. Shaw (1*s*. 6*d*.).

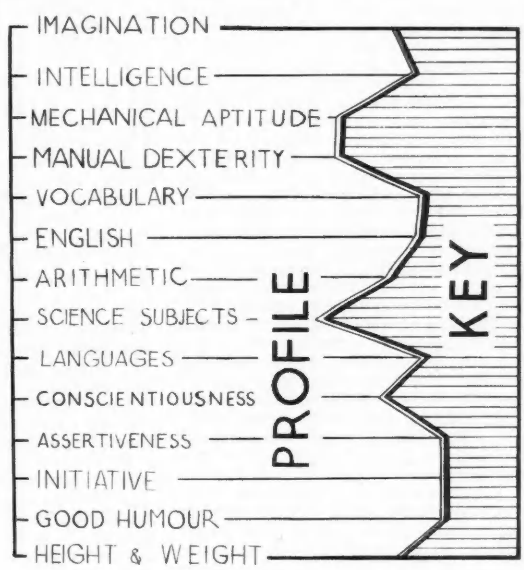


FIG. 2.—Diagrammatic illustration of the principle of vocational guidance. Assessments of the candidate's characteristics are made by means of special tests and the results are plotted on horizontal scales. The points are joined by straight lines to give the jagged outline or profile which may then be compared with a series of keys or reversed profiles representing the ideal requirements for various professions. The illustration depicts the key for the job of salesman; the applicant is apparently a perfect specimen. (*after* Cattell).

Science and the Citizen

How much can one attempt to say in a broadcast talk? The question is prompted by the suggestion of the radio critic of *The Observer*, W. E. Williams, that brevity is the merit common to radio talks—"10 minutes is the right length—with another five for such masters as Mr. Middleton". Perhaps DISCOVERY readers might care to express their opinions on this matter. For ourselves we feel that in the field of scientific broadcasts such brevity is liable to degenerate into scrappiness except when, as in *Your Questions Answered* and *Facts and Figures*, the talk is designed as a straightforward answer to a relatively simple and straightforward question. From our own listening experience we should say that very little information can be conveyed in a broadcast lasting only ten minutes, particularly if an arts-trained producer expects the scientist to talk down to his audience, a condition which means that it will take twice as long as to say half of what should be said. The scrappiness of many radio talks makes itself obvious when the spoken word is printed. This is the main impression created when one peruses *Science Broadcasts*, a book of reprinted science talks published by Littlebury of Worcester. Over the air these talks probably sounded quite good and may have been thoroughly enjoyable. Most of them are totally unsuited to publication in anything more permanent than *The Listener*. Another book, *Science at Your Service* (Allen & Unwin, pp. 102, 6s.), which we found rather more readable, contains twelve talks broadcast during the winter of 1943-44 under that title. The participants in that series, including Dr. Julian Huxley, Sir Lawrence Bragg, Sir Edward Appleton and Professor E. C. Bullard, were given a rather larger ration of radio time and consequently the factual skeleton of their radio lectures was not only more solid and less rickety than usual but better covered with verbal flesh. The person likely to find these two volumes of most use will be the would-be broadcaster who wants to learn the craft of preparing a broadcast talk. Those who aspire to something more ambitious than the radio talk would gain some useful ideas from a script of Julian Huxley's which has been published under the title *T. H. Huxley: A New Judgment* (Watts).

Night Sky in July

M. DAVIDSON, D.Sc., F.R.A.S.

The Moon.—New moon occurs on July 9d. 13h. 35m. U.T., and full moon on July 25d. 02h. 25m. The following conjunctions take place:

July			
5d. 06h.	Mars in conjunction with the moon	Mars	3° N.
6d. 02h.	Venus ,,	Venus	0.4 N.
11d. 10h.	Mercury ,,	Mercury	2 S.
14d. 12h.	Jupiter ,,	Jupiter	4 S.

The Planets.—Mercury is visible in the evening hours, setting at 21h. 26m., 21h. 15m., and 20h. 22m. at the beginning, middle, and end of the month respectively. The planet attains its greatest easterly elongation on July 23, when it will be 27° from the sun. Venus rises in the early morning hours, at 1h. 30m. and 1h. 08m. at the beginning and end of the month respectively. Mars rises at 0h. 53m., 0h. 21m., and 23h. 48m., at the beginning, middle, and end of July respectively, and moves from the constellation of Aries into Taurus during the month. Jupiter sets at 23h. 15m., 22h. 22m. and 21h. 27m. at the beginning, middle, and end of the month respectively, and is fairly close to ζ Geminorum. Its distance from the earth varies from 935 to 929 million miles during the month. Saturn sets about quarter of an hour before the sun on July 1 and is not favourably situated for observation..

Times of rising and setting of the sun and moon are as follows, the latitude of Greenwich being assumed:

July	Sunrise	Sunset
1	3h. 46m.	20h. 21m.
15	3h. 59m.	20h. 12m.
31	4h. 21m.	19h. 51m.

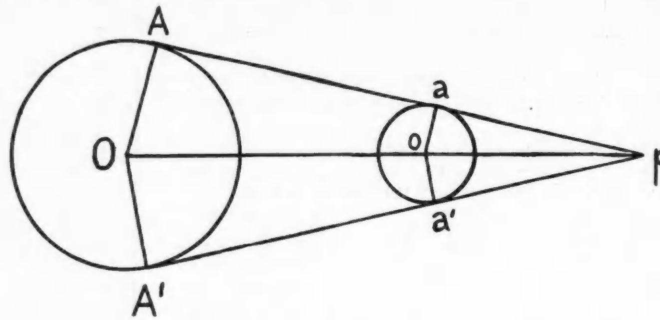
July	Moonrise	Moonset
1	23h. 55m.	10h. 20m.
15	10h. 25m.	23h. 12m.
31	23h. 03m.	12h. 10m.

Total Eclipse of the Sun.—There will be a total eclipse of the sun on July 9, visible as a partial eclipse at Greenwich. It begins at 10h. 59·6m. and ends at 15h. 55·2m., but the central eclipse begins at 12h. 13·8m. and ends at 14h. 40·9m. At Greenwich the eclipse begins at 12h. 45m. and ends at 15h. 11m., the magnitude of the eclipse there being 0.61. The central line commences in longitude 115° 57'W. and latitude +44° 23', ending in longitude 72° 33'E. and latitude +41° 43'.

The path of the moon's shadow will pass over the south-eastern corner of Saskatchewan, across Hudson Bay, Norway, Sweden and across Siberia, ending in the Kirgiz Republic of U.S.S.R.

Some readers may want to know why there can be an eclipse which appears as totality over a long narrow track while in other parts of the earth it appears as a partial eclipse or is invisible. The following explanation will make the matter clearer.

In Fig. 1 let the large and small circles



represent the circles formed by the intersection of a plane with the sun and moon, this plane passing through the centres O and o of each body. This plane will be taken as the plane of the paper. Let Aa and $A'a'$ be the common tangents to the two circles and let these meet in the point P. Obviously an observer anywhere inside the space $aoa'P$ will be unable to see any portion of the sun. If the figure $aoa'P$ is rotated round oP a cone will be traced out, and if any portion of the surface of the earth comes within this cone an observer there will see a total eclipse of the sun.

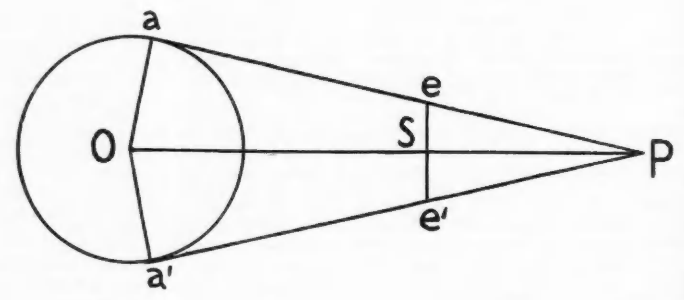
The triangles AOP and aoP are similar, and hence $AO/ao = OP/op$. The ratio of and radii of the sun and moon (that is AO/ao) is 400, and if d is the distance Oo between the centres of the sun and moon, and x is the distance oP from the centre of the moon to the apex P of the cone, the above relationship gives.

$$\frac{d+x}{x} = 400$$

At the time of the eclipse the distance d is about 94,322,000 miles, and hence x is 236,395 miles. During the eclipse the distance of the moon from the earth varies a little, but we can take its value as 234,000 miles.

In Fig. 2 let oa be the radius of the moon and ese' the width of the shadow cast by the moon on a portion of the earth's surface. From the similar triangles oaP and seP we have the relation $es/ao = sP/oP$. It has been shown that the distance between the centres of the earth and moon is about 234,000 miles but as ese' is on the side of the earth next to the moon it could be nearly 4,000 miles less than the above figures from the centre of the moon. Hence ese' might possibly be only 230,000 miles from the centre of the moon, and since oP was found to be 236,395 miles, sP could be $236{,}395 - 230{,}000 = 6{,}395$ miles. Hence $es/ao = 6{,}395/236{,}395 = 0{\cdot}027$; since ao is 1080 miles, $es = 29$ miles. The width ee' is twice this, or 58 miles, but actually the width is less than this because the extreme case has been taken, that is, the position of ee' is considered 4,000 miles nearer to the moon than the earth's centre—a very great exaggeration. If ee' is taken to be as far from the moon as the centre of the earth, which is an exaggeration in the other direction, the width of the shadow would be less than 18 miles. The actual width will lie somewhere between these extremes, generally speaking, but the figures are only approximate.

It will be seen from the above results why the width of the line of totality is comparatively small, varying with the circumstances, but not usually exceeding 60 miles, and often considerably less than this.



Far and Near

National Certificates in Metallurgy

THE Ministry of Education has announced details of a scheme for the award of National Certificates in Metallurgy. Two grades of Certificate will be awarded, ordinary and higher—and examinations will be held for the ordinary certificate in 1946.

The Certificates will be awarded on conditions agreed between the Ministry, the Iron and Steel Institute, the Institution of Mining and Metallurgy, and the Institute of Metals, and the Institute of British Foundrymen will co-operate in the case of advanced courses which include specialised instructions in foundry work.

Colleges and schools with candidates wishing to study for the Certificate as from the beginning of the school year 1945-46 are asked to apply to the Ministry for approval of their schemes.

Intending students can obtain information from their local Technical Colleges or from the Secretary to the Joint Committee for National Certificates in Metallurgy, 4 Grosvenor Gardens, London, S.W.1.

News from Russia

A SPECIAL penicillin commission has been set up in the U.S.S.R. by the People's Commissariat for Health Protection. Mass production is to commence as soon as possible and two factories in Moscow are now being equipped for the work.

A jubilee session of the Academy of Sciences of the U.S.S.R. was held in Moscow and Leningrad from June 15 to 28 to mark the Academy's 220th anniversary.

In last month's issue we published a short article about Ilya Metchnikoff. *Soviet War News* reports that the Council of People's Commissars of the U.S.S.R. has decided to build a monument to him in Moscow and to place memorial plaques on buildings where he lived and worked; to award annually a "Metchnikoff Medal" for the most outstanding work by a Soviet or foreign scientist in the sphere of microbiology, immunology or epidemiology; to institute two "Ilya Metchnikoff" Prizes—one of 50,000 roubles and one of 25,000 roubles—for annual award to Soviet scientists; to give Metchnikoff's name to the All-Union Society of Microbiologists and the Odessa State University; to institute 15 Metchnikoff scholarships in higher medical schools.

An academic edition of Metchnikov's works and correspondence is being prepared and a popular film on the scientist's life and work is to be made.

Predigested Food for Holland

To prevent the death by starvation of over 60,000 Dutch persons who have reached a condition that makes normal digestion of food almost impossible, two shipments totalling 16,000 lb. of a protein preparation known as Amigen have been flown to Holland from the United States. In producing Amigen, crude hog pancreas is added to casein. The enzymes of the pancreas break down the casein into amino-acids during a two-day incubation period and these substances are readily assimilable into the blood-stream. These shipments supplement supplies in the United Kingdom which have already been drawn upon to aid the Netherlands.

German Tribute to British Science

BRITISH scientists played a big part in helping to win the U-boat war, constantly causing the enemy to change his U-boat tactics. Making allowances for the well-known German "stab in the back" propaganda technique, there is interest in the words of a pep-talk Admiral Doenitz made to German flag-officers at Weimar in the early days of 1944, and his comments on British science, particularly radiolocation.

"At the end of last year and the beginning of this," he said, "one development became very obvious which long ago, even in peacetime, had been feared—that the enemy might deprive the U-boat of its essential feature—the element of surprise—by means of radiolocation. With these methods he has conquered the U-boat menace. The scientists who created radiolocation have been called the saviours of their country. So, it was not superior strategy or tactics that gave him success in the U-boat war, but superiority in scientific research. Germany made the great mistake of calling up her scientists into the armed forces instead of letting them continue their researches, and it was not until eight months later that the Reichswehr ordered the release and exemption of scientists from military service."

Electron Microscope for Cancer Research

A ONE-TON electron microscope powerful enough to magnify the windpipes of mosquitoes to a size of approximately two inches has been added to the range of scientific instruments available for the study of cancer at the National Cancer Institute, Bethesda, Surgeon General Thomas Parran, of the U.S. Public Health Service, announces. Although installed in the National Cancer Institute, the microscope will not be restricted to the study of cancer but will be available to other divisions of the National Institute of Health. The microscope, which was built by the Radio Corporation of America and cost 13,000 dollars is the nineteenth in the United States. Direct magnifications of 10,000 to 75,000 diameters are possible with its use.

Fuels for Jet Planes

A LABORATORY for the study of fuels and lubricants for jet-propulsion aircraft has been built at Wood River, Ill., by the Shell Oil Co.

Making Sea Water Drinkable

ONE of the many problems which have confronted British scientists during the war has been that of rendering sea water drinkable. So far as the problem affected airmen forced down into the sea, two important considerations, space and weight, had to be borne in mind in producing emergency "desalting" equipment to be carried—first in an aircraft, and then in a small dinghy.

Eventually, chemists of the Permutit Company, Chiswick, working in association with the Ministry of Aircraft Production produced a desalting apparatus in a simple and compact form, suitable even for weak or wounded men's use. The apparatus is in the form of a box about the size of a half-pound packet of tea. The box is made of transparent plastic, and is used as a drinking vessel. Inside is a collapsible bag. And all the "ditched" airman has to do is to take out this bag, pour in a quantity of sea water, drop in some cubes, close the bag, and, after a period, squeeze fresh water through a spout at the bottom into the box. When all the fresh water has been squeezed out, the bag is rinsed in the sea and is then ready to produce another supply. The process was devised by British scientists who passed on the details to the United States. The Americans have now developed a similar apparatus. Over 20,000 of these boxes have been sent to Eastern Air Command, South East Asia. Each of these, though taking up less space than a pint of water, will produce four and a half pints. They will be packed into the dinghies carried by all aircraft flying over the sea, several being provided for each member of the crew.

The desalting process depends upon the same basic principles of base- and anion-exchange as are used in household and industrial water-softening.

First Colonial Research Fellowship

THE first Fellow to take up work under the recently instituted Colonial Research Fellowship scheme, has left for the Gold Coast. She is Miss Peter Ady, who is to make an intensive study of the distribution of incomes and the organisation of village economy among the small African producers in the Colony's important cocoa industry.

Miss Ady, who is a graduate of Oxford, has recently been doing research work in statistics with the Institute of Statistics at Oxford. She was born in Burma, and graduated at the University of Rangoon.

The Fellowships, which are awarded by the Secretary of State on the advice of the Colonial Research Committee, are financed by the Colonial Development and Welfare Act. Provision has been made for 25 such Fellowships within the next five years, but war-time shortage of personnel is at the moment restricting the development of the scheme.

The granting of further fellowships to enable the research work to be pursued in other Colonies will probably be announced shortly.

Personal Notes

ALEXANDER FERSMAN, the famous Soviet geologist, died on May 20 at the age of 61. He will be remembered for his part

in the work of the Commission for the Study of Natural Resources of Russia. He was awarded a Stalin Prize for his scientific services. In 1943 British geologists awarded him the Woolaston Medal.

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SIR JACK DRUMMOND, F.R.S., D.Sc., F.R.I.C., Chief Scientific Adviser to the Ministry of Food, has been appointed to the post of Director-in-Charge of the whole of the scientific research organisation of Boots Pure Drug Company, Ltd. Sir Jack Drummond has resigned the Chair of Bio-chemistry at University College, London, which he has held since 1922, but will not take up his new appointment until the food situation has improved.

Protection *v* Technical Progress

A STRIKING illustration of how technological advance may result in legislation that was introduced to encourage one industry or to provide revenue becoming a serious handicap to another industry is quoted in the Report of the Hydrocarbon Oil Duties Committee (Stationery Office, Cmd. 6615, price 3d.). Turpentine and pinene (the terpene which is the main constituent of turpentine) were rendered dutiable at the rate of 9d. a gallon under the scheme that sought to protect home producers of light oils suitable for use in automobile engines. But pinene is the essential raw material for the manufacture of "synthetic" camphor, an essential ingredient of celluloid and one for which no indigenous substitute is possible. The effect of the duty on pinene and turpentine has been to offset the protection of the British manufacturer in the home market which is accomplished by means of a 10% duty on imported camphor. A similar effect was created in other branches of chemical industry. The report comments that "the indirect effect of the hydrocarbon oil duties on the chemical industry has unquestionably been great. There is little doubt that the existence of those duties and the fear that they might at some future time be raised to a still higher level has prevented the development in this country of new processes using those oils as raw materials."

The Hydrocarbon Oil Duties Committee was set up last year to consider the effect of the hydrocarbon oil duties on the supply of raw materials to the development of the British chemical industry and the extent to which any change in those duties would affect industries in the production of similar products from coal.

The committee considers that petrol and coal are primarily complementary sources of raw materials for chemical synthesis, the carbonisation of coal yielding aromatic compounds whereas those from the "cracking" of petroleum are largely aliphatic compounds. Both are necessary to modern organic chemical industry, and the committee expresses the view that "there is a real danger that if the present position is maintained fiscal rather than technical considerations will dictate the future course of development, even possibly to the extent of stifling entirely certain lines of development". The report indicates how it would be possible to provide duty-free raw materials for organic syntheses without reducing the protection to British producers of light hydrocarbon oils.

The relation between petroleum and ethyl alcohol as bases for synthesis is different from that between petroleum and coal. As sources of important aliphatic chemicals, they are competitive, especially as regards acetic acid, acetic anhydride and acetone which are used in very substantial quantities in the artificial silk industry. They are also competitive as raw materials in the synthetic rubber industry and the selection of ethyl alcohol for the vast war-time synthetic rubber production plan of the U.S.A., purely on the criterion of the then available chemical plant-fabricating capacity, has already been described in this journal (December, 1944). However, petroleum cracking yields, additionally, valuable chemicals which it is not possible to obtain from processing ethyl alcohol.

In this country a synthetic chemical industry based on petroleum has been at a double disadvantage as compared with that based on the fermentation of molasses for ethyl alcohol. This has arisen not only because of the 9d. a gallon duty on imported hydrocarbon oil but also because of the allowance of 5d. per proof gallon made by the Government to the methylators of alcohol. The Committee set up to consider the removal of this allowance (Stationery Office, *Removal of Certain Excise Restrictions on Distillation and of Allowances on Industrial Alcohol and Exported Spirits*, Cmd. 6622, Price 4d.) have come to the conclusion that a large part of the allowance has been in effect a subsidy to the fermentation alcohol industry. This allowance is of a composite nature, being made up of 2d. per proof gallon paid since 1921 (this was in the nature of a protection against foreign competition) *plus* an allowance of 3d. per gallon paid by the Exchequer since 1906 to methylators as compensation for the restrictions placed upon manufacturers as regards the methods of production they might use. The main restriction, which derived from the method of supervision and book-keeping by the Excise, was the prohibition of simultaneous brewing and distilling. The need for these restrictions was, of course, the large amount of revenue which it was necessary to safeguard. The duty on alcohol has always been high and at present amounts to £6 17s. 6d. per proof gallon; but denatured alcohol for approved industrial uses is available, under Excise supervision, duty-free. In the light of modern methods of production it is admitted that 3d. per proof gallon is excessive compensation for the restrictions imposed and that a large part of the £900,000 per annum paid in respect of these allowances by the Exchequer before the war was, in effect, a subsidy. On the recommendation of the Committee set up by Sir Kingsley Wood in 1943 the 5d. per gallon allowance was abolished by Sir John Anderson in the recent Finance Bill.

As the Committee state, there is little reason to doubt that the benefit of the allowance was passed by the distiller, through the methylator, to the consumer and consequently consideration was given to the effect the abolition of the allowance might have on the consuming industries. While there can be little doubt that an increase in the cost of industrial alcohol would occur there was doubt as to the actual extent and divergence of opinion as to what effect on the consuming industries. Broadly speaking, where alcohol or its derivatives enter an industry as a process chemical the increase in the cost of the finished material is likely to be imperceptible. Only where alcohol forms a considerable part of the finished product is the effect likely to be serious. As examples of this may be cited cheap toilet waters and perfumes (the increase would be of the order of about 20 per cent. on pre-war prices) and petrol-alcohol blends of motor spirit (the manufacture of which would be expected to become completely uneconomical).

On extraordinary omission from this report is to be noticed. No evidence, it appears, was asked for or offered concerning the repercussions of the removal of the hydrocarbon oils duty, or the excise allowance on methylated spirits, on the economy of those Colonies whose welfare is bound up with the sugar industry, from which molasses is derived as a byproduct to be used as the raw material for the fermentation alcohol industry.

In the U.S.A., where petroleum is indigenous in quantity and most of the molasses is imported by relatively short sea routes to west-coast distilleries the difference between the cost of manufacture of alcohol from molasses and that from petroleum is not regarded as significant. In this country both materials are imported in tankers over long sea routes, with an orientation in favour of molasses against which must be set the fact that straight molasses contains only about 50 per cent. of sugar and that approximately half the carbon of this sugar is evolved during the fermentation in the form of carbon dioxide. Petroleum oils on the other hand are, potentially at least, capable of a greater degree of utilisation and provide (with some flexibility) a wider range of important chemicals.

The mutual repercussions of the two great industries—the (to us) new synthetic chemical industry based on petroleum (producing its quota of ethyl alcohol among other things) and the old-established fermentation alcohol industry which has hitherto been the basis for producing certain important chemicals by synthetic means—will provide a focus of interest during the next decade that follows the removal of fiscal impedimenta. It would be rash indeed to predict to what level of adjustment the inevitable competition that will arise will ultimately be resolved.

ERRATA

BY an unfortunate error which no one regrets more than does the Editor, Fig. 7 (the Thomas Arithmometer) to the article "Machinery in Mathematics" in the May issue was inverted. We do not think, however, that any reader is likely to have been misled by this mistake as the inversion was quite obvious from the scale at the bottom of the machine.

In the April issue *r* (radius of the curve in chains) should have appeared as the denominator to the formula giving superelevation in inches. We are grateful to the readers who wrote pointing out this mistake.

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